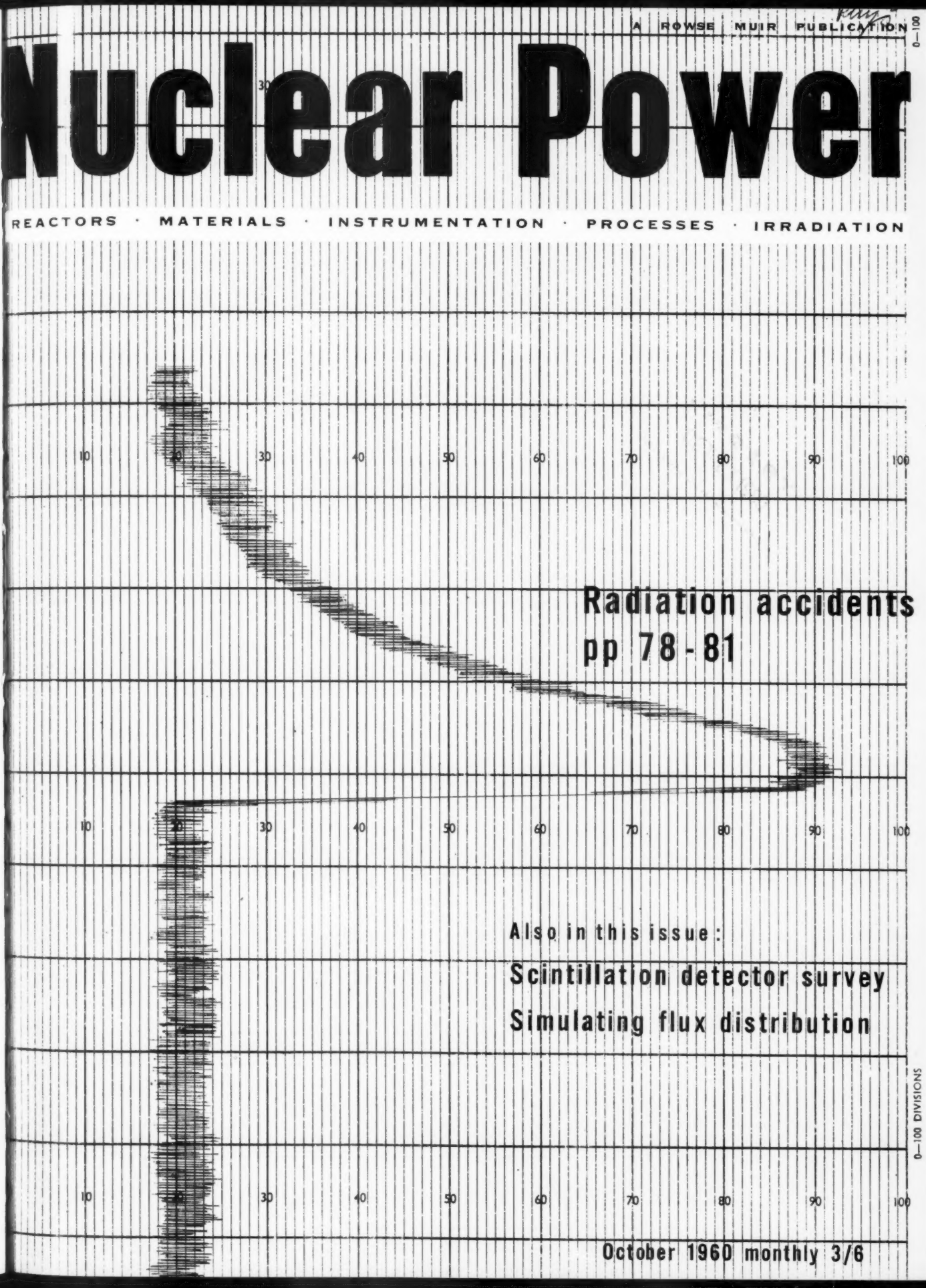
A ROWSE MUIR PUBLICATION

Nuclear Power

REACTORS · MATERIALS · INSTRUMENTATION · PROCESSES · IRRADIATION



Radiation accidents
pp 78-81

Also in this issue:

Scintillation detector survey

Simulating flux distribution

October 1960 monthly 3/6

You'll need to know more about...

NuFive

and

NuSeven

NEW ALL-POSITION electrodes from

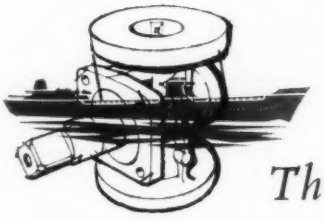
LINCOLN

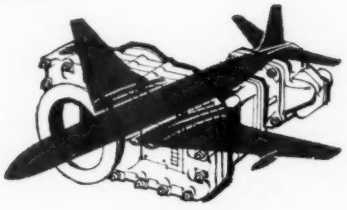
Write today for further details to:

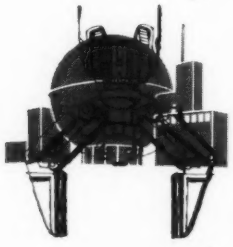
LINCOLN ELECTRIC CO LTD · WELWYN GARDEN CITY · HERTS

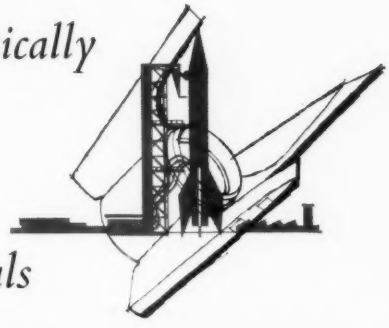
Telephone: Welwyn Garden City 920 (5 lines) 4581 (5 lines)

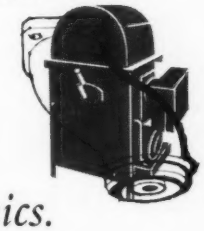
Kanigen *a hard, non-porous corrosion-resistant plate, gives complete uniform coverage even to the most intricately shaped parts. Thickness can be controlled to fine limits. Being chemically deposited Kanigen can be applied to practically all metals in commercial use. It can also be applied to non-conductors such as plastics and ceramics.*











KANIGEN
ALBRIGHT & WILSON

Approved under DTD 900/4505 and ARB A1/5112/57. Already widely used throughout industry including aircraft and nuclear applications. Kanigen is the registered trade mark of Albright & Wilson (Mfg) Ltd.

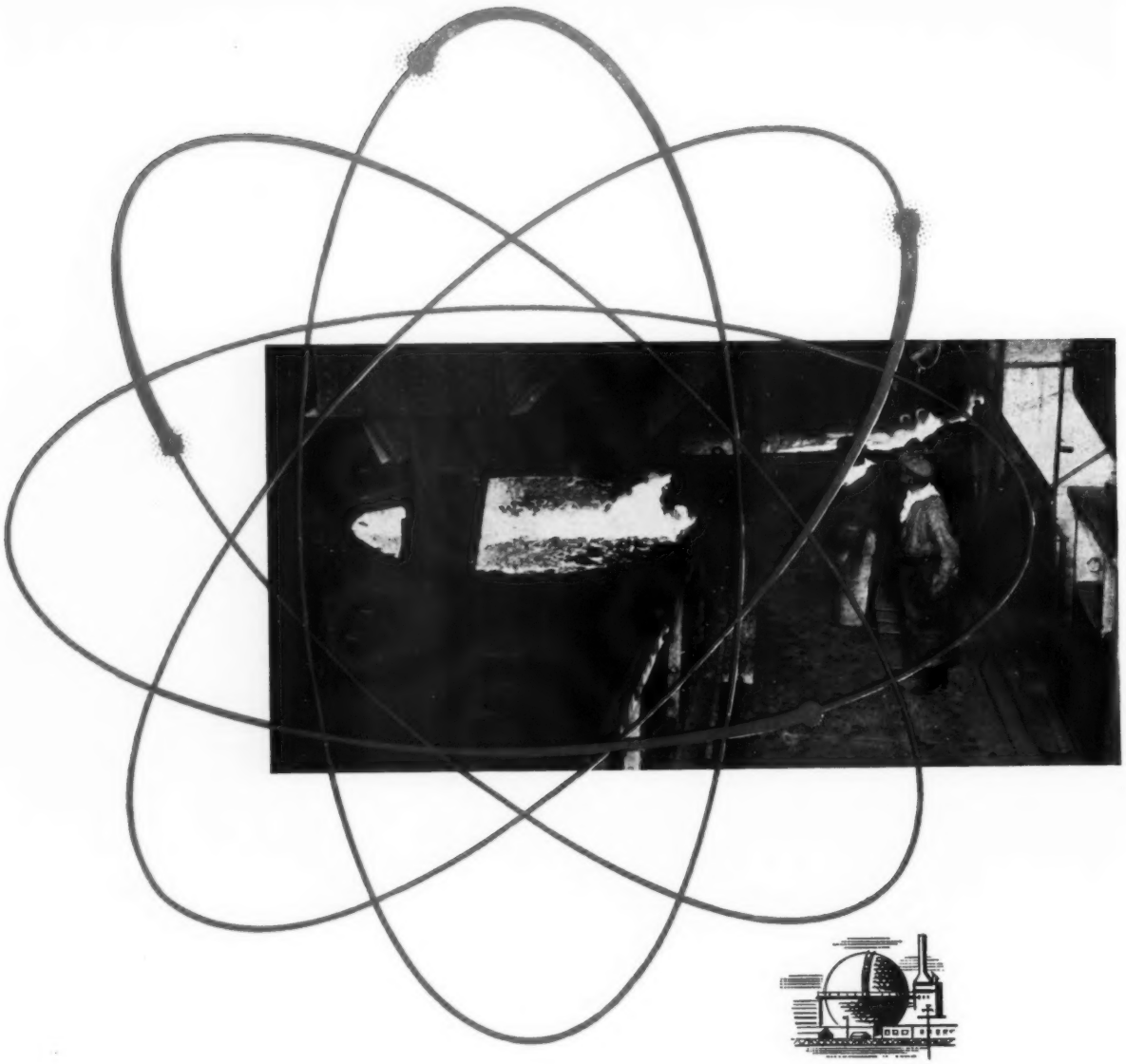
For full information write to:

ALBRIGHT & WILSON (MFG) LTD

Kanigen Department (NP)

1 KNIGHTSBRIDGE GREEN · LONDON SW1 · TEL KENSINGTON 3422

cnw/701



Specially developed steels — for the nucleonics industry

Colvilles pride themselves in being abreast of every development in the nuclear field. Their range of Special Steels has been developed to that purpose.

DUCOL W.30	ABRAZO	COLMO	COLCLAD	CORTEN	COLTUF
High Tensile Weldable Steel	Abrasion Resisting Steel	Creep Resisting Steel	Stainless Nickel & Monel Clad Steels	High Strength Corrosion Resisting Steel	Notch Tough Steel

COLVILLES

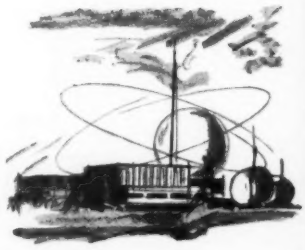
FITNESS FOR PURPOSE STEELS

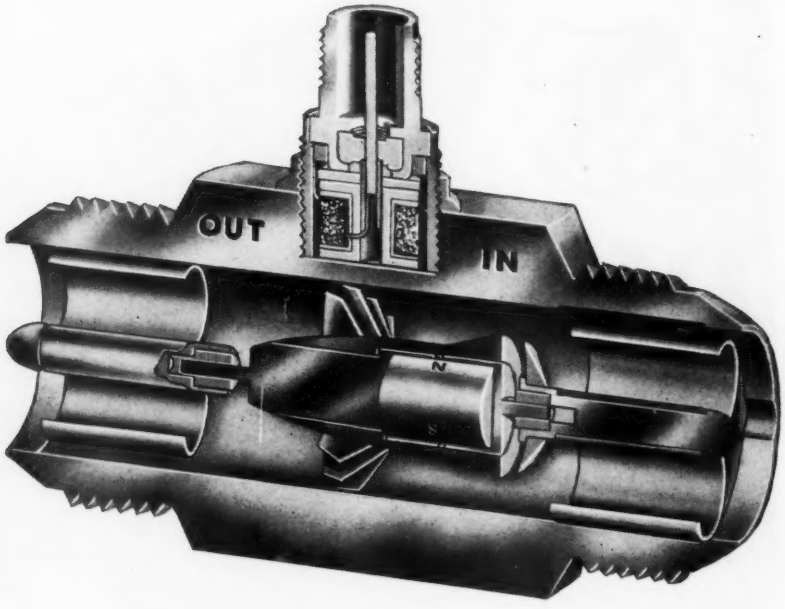
COLVILLES LTD 195 West George Street Glasgow C.2

Wherever information on fluid flow is required,

the de Havilland POTTERMETER

sets new standards of accuracy and reliability





This new turbine-type flowmeter enables major advances to be made in the techniques of flow measurement and control. The de Havilland Pottermeter is the only flowmeter which offers all these features:

Contains only one moving part—no thrust bearings—operates with a minimum of maintenance at high temperatures and pressures

Accuracy to ± 0·1% or better on repetition work, ± 0·5% or better over a 20·1 range. Calibration remains constant for a variety of liquids over wide flow ranges.

No larger than the pipeline in which it is installed—may be mounted in any attitude.

Can be supplied with indicating, recording and process control equipment— gives digital presentation of results.

Can measure volumetric or mass flows.

Models available to measure flows from 0·1 to 40,000 Imperial gallons per minute, at a wide range of operating pressures. Larger and smaller sizes made to order.

Can measure flow of any liquid or gas, irrespective of its lubricating or non-lubricating properties, at temperatures ranging from −455°F to 1500°F.

Manufactured as standard in stainless steel—can be made in any non-magnetic material.

Rapid response rate permits transient flow studies.

Write now for further details to:

DE HAVILLAND PROPELLERS LIMITED

(INDUSTRIAL SALES DIVISION) Hatfield, Herts

Circle **No 5** on reply card for further details

NOW manufactured in the UNITED KINGDOM

1850 ASHCROFT U.S.A.

DURAGAUGES

Specially designed for the most exacting operating conditions in the Oil Refining and Chemical Industries, these Gauges have become standard equipment in many plants throughout the World.

PRESSURE-VACUUM OR COMPOUND TYPES
Manufactured by DEWRANCE under exclusive licence
Full details on request

DEWRANCE
AND COMPANY LIMITED

GREAT DOVER STREET, LONDON, S.E.1.
Telephone: HOP 3100 Telegrams: DEWRANCE LONDON

WORKS: LONDON · BRADFORD
DUMBARTON · HILLINGTON

CAST IRON VESSELS

for the

ATOMIC ENERGY AUTHORITY

Approved by Lloyd's for Class II welding for pressure vessels

One of the battery of special Cast Iron Vessels supplied to the U.K. Atomic Energy Authority. The body of the vessel is approximately 5ft. 8in. outside diameter by 6ft. 3in. high and the complete vessel weighs approximately 30 tons.

WIDNES

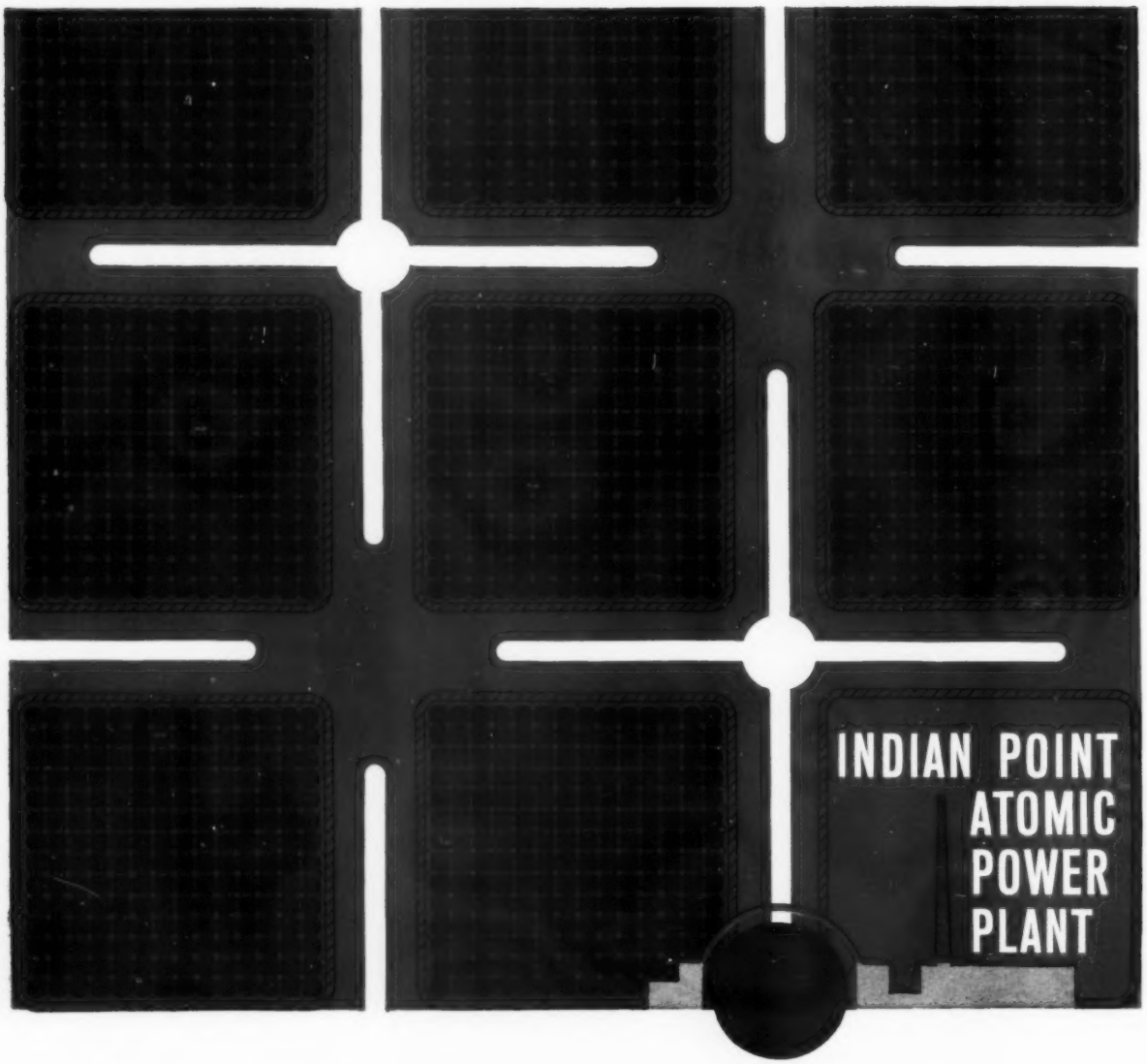
ESTABLISHED 1841

FOUNDRY & ENGINEERING CO. LTD.

LUGSDALE ROAD, WIDNES, LANCS. TEL. 2251/4 GRAMS. 'FOUNDRY WIDNES'

W40

Circle **No 7** on reply card for further details



USING MALLINCKRODT URANIUM–93% ENRICHMENT

This reactor, as well as those of Commonwealth Edison Company and Yankee Atomic Electric Company, depends upon commercially produced nuclear fuels. The uranium loading of all three will be entirely or partly Mallinckrodt UO_2. ◆ The Indian Point reactor, designed and manufactured by Babcock and Wilcox Company, will use over 2000 pounds of Mallinckrodt UO_2 (93% enrichment). The balance of the fuel will be thorium oxide. This 275,000-kilowatt plant is owned by Consolidated Edison Company. ◆ Whether power, propulsion or experimental—domestic or overseas—Mallinckrodt has unequaled experience in producing uranium fuel materials. Mallinckrodt now offers over fifteen different forms of uranium compounds and metal . . . and can deliver completed fuel elements by working with metal fabricators. For consultation on your nuclear fuel problems, write or call Mallinckrodt.

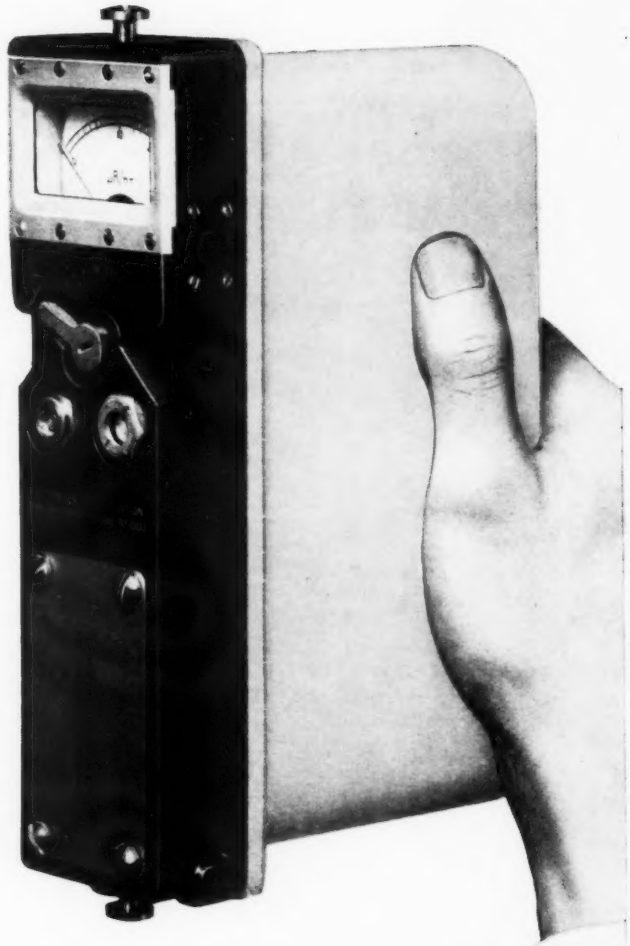
MALLINCKRODT NUCLEAR CORPORATION · ST. LOUIS 7, MO.
THE WORLD'S FIRST AND LEADING PRODUCER OF NUCLEAR FUELS

NEW SCINTILLATION MONITOR

for the detection and measurement of gamma radiations down to natural background level.

- ★ **transistorized**
- ★ **highly sensitive**
- ★ **fast response time**
- ★ **three meter ranges**
  - **0 - 0·03 mR/hr**
  - **0 - 0·3 mR/hr**
  - **0 - 3·0 mR/hr**
- ★ **meter illumination**
- ★ **hermetically sealed**
- ★ **500 hrs. battery life**
- ★ **compact $8\frac{1}{2} \times 2\frac{1}{2} \times 5\frac{1}{2}$ ins.**
- ★ **lightweight - 4 lbs.**
- ★ **rugged construction**

DESIGNED IN CONJUNCTION WITH THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY.



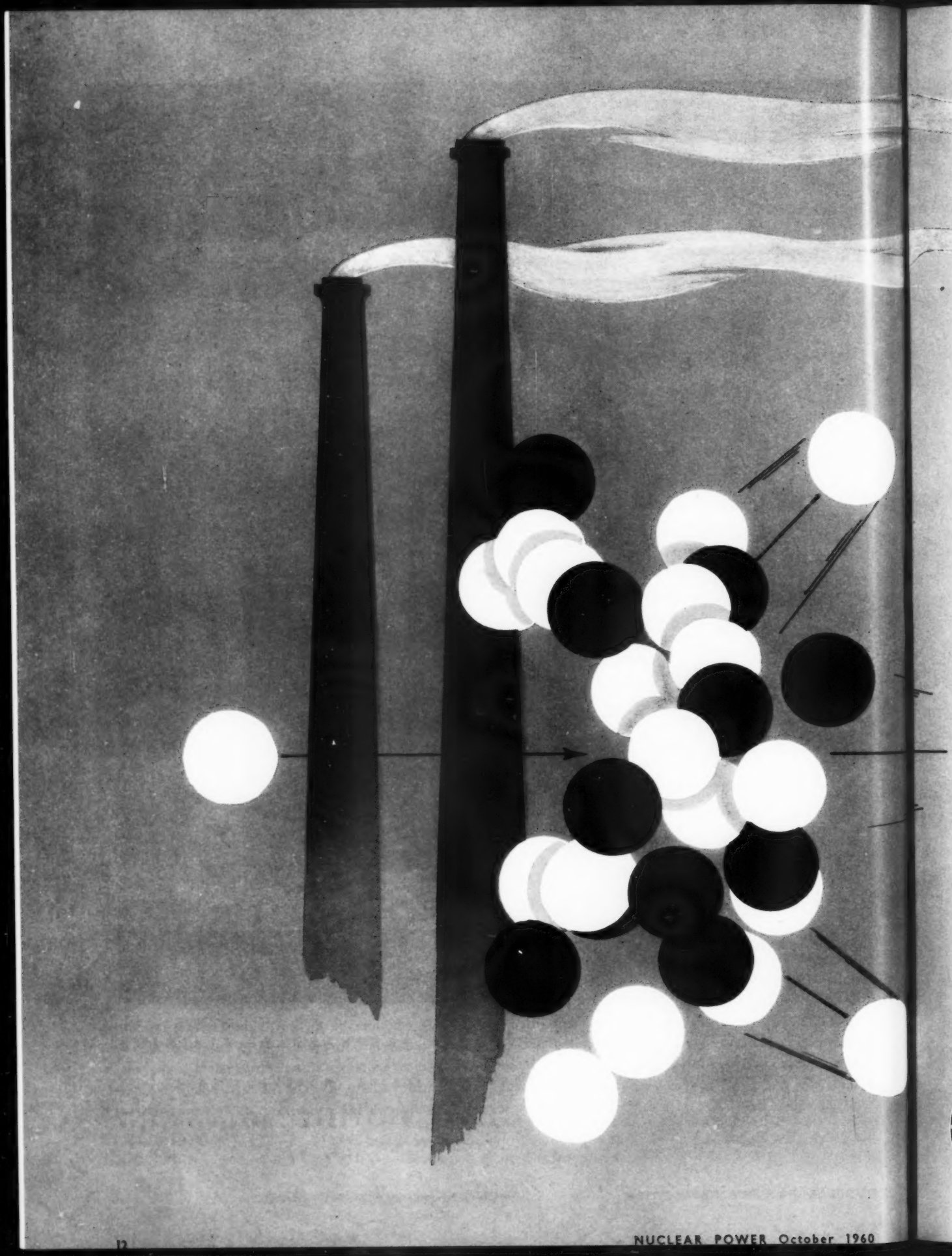
general radiological
LIMITED

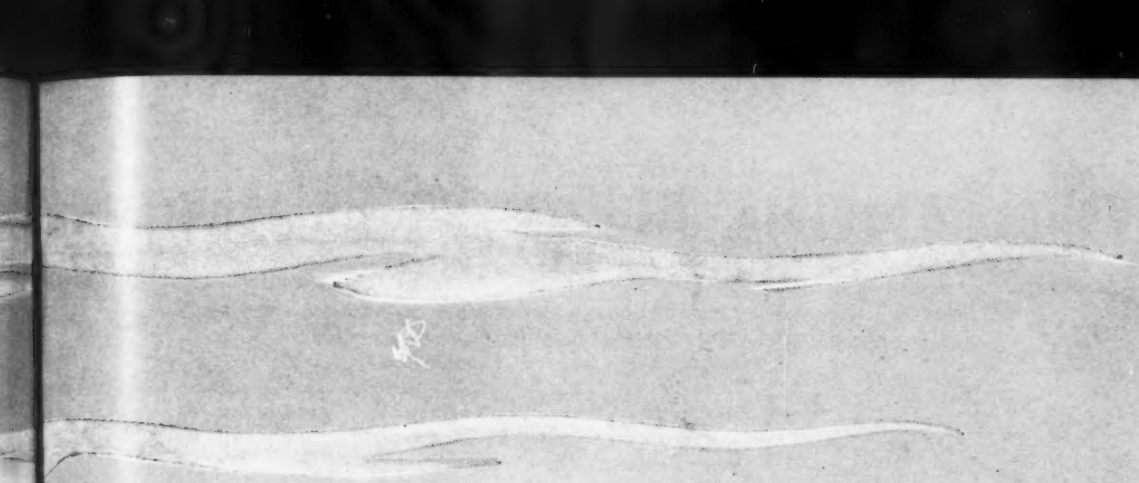
NUCLEAR ENGINEERING DIVISION

COUNTY BUILDING, HONEYPOT LANE

STANMORE MIDDLESEX WORdsworth 4300

Circle **No 9** on reply card for further details





PERFORMANCE determines the C.E.G.B's choice of WAKEFIELD-DICK LUBRICANTS

NUCLEAR

Nucleol is a range of oils and greases resistant to radiation. In the new nuclear power stations, Berkeley and Dungeness, Wakefield-Dick lubricants have been chosen to play a major part in the smooth-running generation of power.

CONVENTIONAL

Wakefield-Dick lubricants have been the choice in electrical generation since the beginning of the industry. The Central Electricity Generating Board has grown to depend on their unfailing reliability and true economy in use. The latest evidence of this fact is the choice of Wakefield-Dick lubricants for the power stations Skelton Grange B, Uskmouth B and West Thurrock.

INDUSTRIAL WAKEFIELD-DICK LUBRICANTS

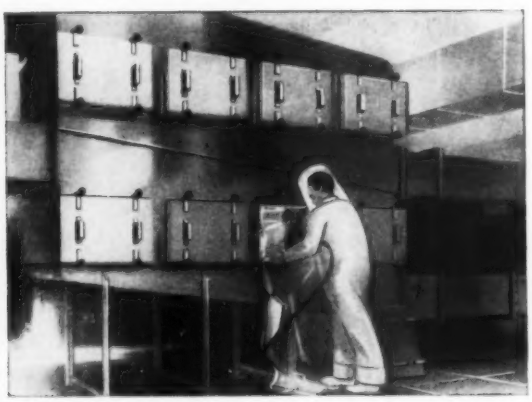
WAKEFIELD-DICK INDUSTRIAL OILS LTD
CASTROL HOUSE · MARYLEBONE ROAD · LONDON, NW1
A Member of the Castrol Group of Companies

This Vokes 'Absolute' filter is the nucleus of

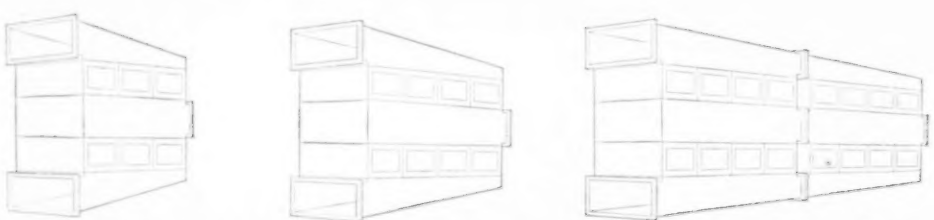
Originally developed for atomic energy work, Vokes 'Absolute' filters have also proved invaluable in biological, pharmaceutical and photographic applications — in fact wherever submicronic particles of dust and dirt can harm expensive equipment and processes. The special filter medium consisting of extremely fine asbestos fibres suspended in a grass-based paper gives a remarkable efficiency of 99.95% against particles in the 0.1 to 0.5 micron range — a figure guaranteed by subjecting every 'Absolute' filter to the methylene blue dust cloud test immediately before despatch. (B.S.S. 2831.)

Other 'Absolute' filters using an all-glass paper filter medium have *guaranteed* efficiencies as high as 99.99% — only 0.01% penetration against a methylene blue dust cloud. For further details please ask for publication HJ.

this Vokes nuclear filtration plant — the Unipak



For the housing of 'Absolute' panels Vokes have designed the UNIPAK, an inexpensive, compact and adaptable structure consisting primarily of a sealing frame housed within an outer metal container. Complete inlet and outlet headers are provided, tailor-made to fit between the ventilation ducting and designed to the duct air velocity specified by the customer. Each 'Absolute' filter is isolated from the next and is easily and quickly fitted or removed by a patented sealing mechanism which, in addition to securing correct alignment of the filter, will not permit the access door to be replaced until it is sealed in position.



Standardized components make possible the simple construction of multiple banks to handle a wide range of air volumes. The alternative layouts available — a few of which are shown in these sketches — make the UNIPAK suitable for most requirements. Our technical engineers are always at hand, however, to advise on special installations.

VOKES

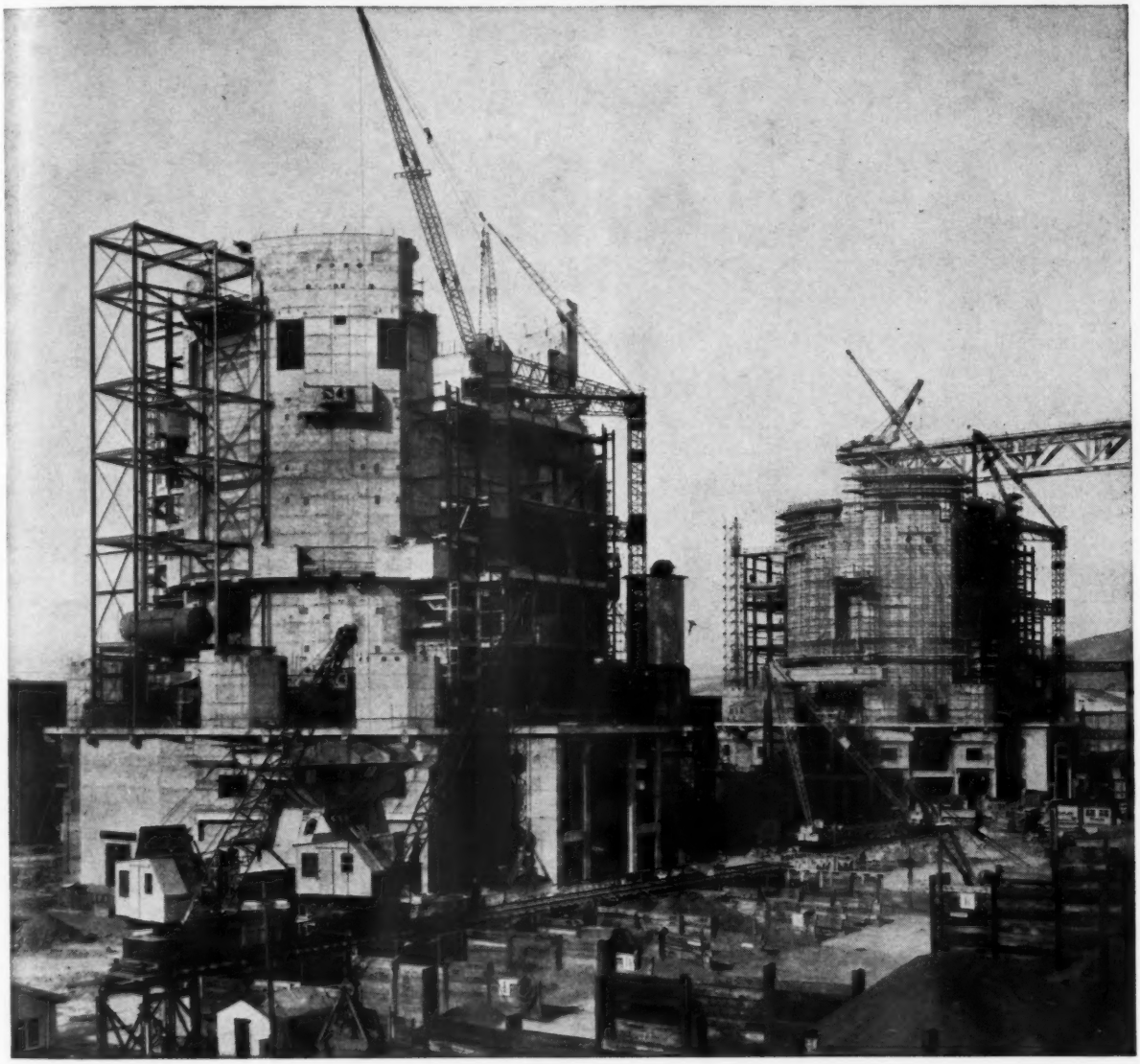
VOKES LIMITED · HENLEY PARK · GUILDFORD · SURREY

Telephone: Guildford 62861 (6 lines)
Telex: 8-535 Vokesacess, Gfd.

Telegrams: Vokesacess, Guildford, Telex
Represented throughout the world

V533

growing day by day...



at Hunterston in Ayrshire, one of the world's first full-scale nuclear power stations which will produce 320,000 kW for the South of Scotland Electricity Board.

G.E.C.
AND SIMON-CARVES LTD

ATOMIC ENERGY GROUP

HEADQUARTERS: THE GENERAL ELECTRIC CO. LTD. OF ENGLAND, ERITH, KENT
393

AMF REACTORS in planning, construction or operation:
Columbus, Ohio
Munich, Germany
Plainsboro, New Jersey
Hamilton, Ontario
Turin, Italy
Sterling Forest, New York
Athens, Greece
Lisbon, Portugal
Rehovoth, Israel
Teheran, Iran
Mayaguez, Puerto Rico
Buffalo, New York
Istanbul, Turkey
Rawalpindi, Pakistan
Tokai-Mura, Japan
Ames, Iowa
Delft, Netherlands
Gainesville, Florida
Seattle, Washington
Los Angeles, California
Vienna, Austria

"Biz AMF i seçtik" 「私達は AMF を選ぶ」 "Wij geven de voorkeur aan AMF" בחרנו ב-A.M.F.
"Nos escolhemos AMF" ہم نے اے ایم ایف پسند کیے "Wir haben AMF gewählt" Ἐξελέξαμεν τὴν A.M.F.
"Hemos escogido AMF" ہم نے ا.م.ف. انتخاب کر لیے "Abbiamo scelto AMF" **"We chose AMF"**

This decision has been made 21 times and in 12 languages by representatives of universities, atomic energy commissions and research institutes charged with the selection of the best research or training reactor for their needs. While the claim of leadership based on quantity of output is often a hollow boast, *in reactor technology and construction it has extraordinary significance.*

Each new reactor or modification has explored unknown areas of performance and manufacture. Experience gained in shrinking these areas literally cannot be duplicated. To *your* needs AMF brings unique knowledge covering design, development, fabrication, engineering-construction and start-up of pool, heavy and light-water tank, and special purpose reactors.

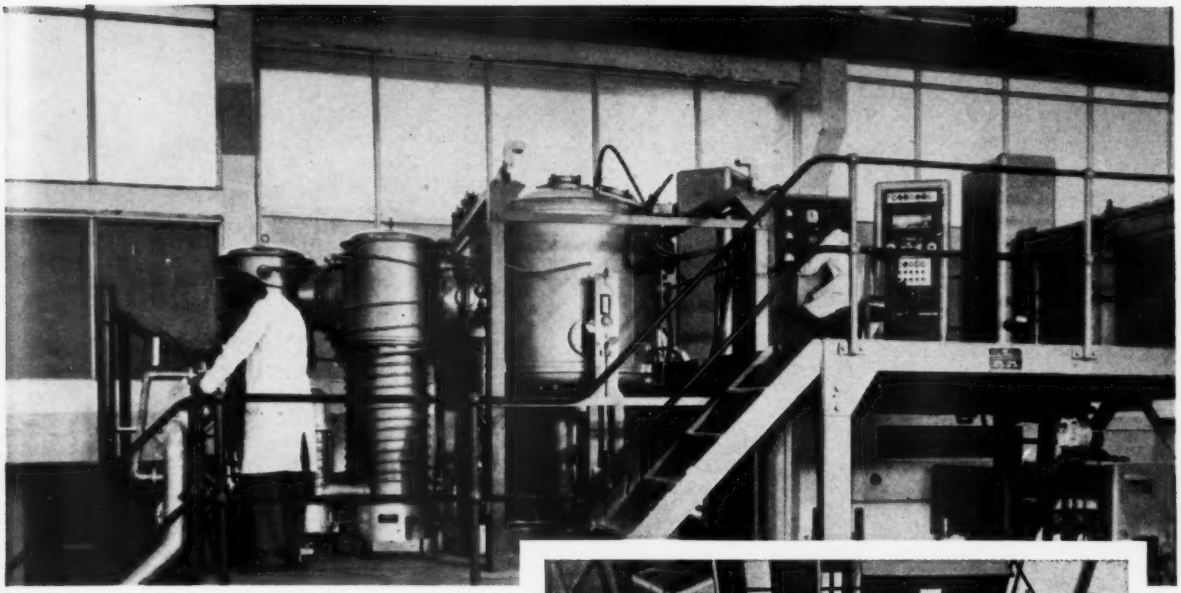
AMF's record starts with the Battelle Memorial Institute's pool-type reactor, in operation since 1956, the pioneering effort in research reactor standardization. The roster of AMF design and fabrication innovations, all of them developed to meet special customer needs, is unmatched.

AMF utilizes its vast mechanical experience in the production of a wide range of reactor components and auxiliary equipment, including: Reactor servicing equipment • Control rod drive assemblies • Standard and heavy-duty manipulators.

International Group
American Machine & Foundry Company
AMF Building • 261 Madison Avenue • New York 16, N. Y.

Overseas plants and offices:
BOLOGNA • CARACAS • GENEVA • LONDON • MEXICO CITY • SÃO PAULO • STOCKHOLM • SYDNEY • TOKYO

Circle No. 14 on reply card for further details



"SPEEDIVAC" VACUUM FURNACES

...about our VACUUM ENGINEERING DIVISION . . .

We do not suddenly—and occasionally—get "big" ideas about vacuum equipment. Although much more has been said about our research and pilot plant activities, we do have a high vacuum engineering division staffed by production engineers with long experience in dealing with the vacuum requirements of heavy industry.

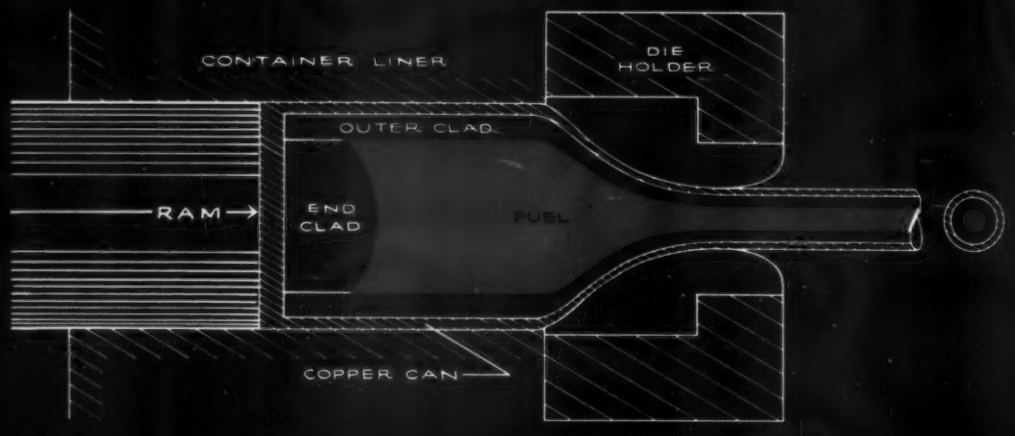
Among the many installations already completed is equipment for vacuum impregnation, freeze drying, vacuum coating, particle accelerators and vacuum furnaces. The furnace illustrated was specially constructed for the Australian Atomic Energy Commission and is being used for uranium melting.

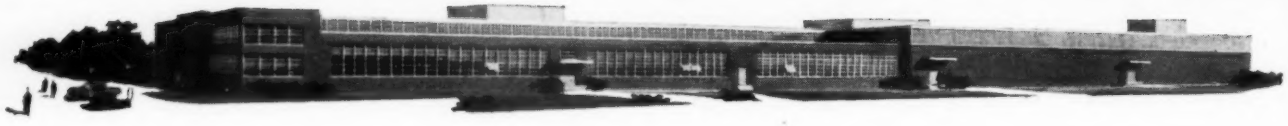
Illustrated is a 200 kg capacity bottom pouring furnace built for the Australian Atomic Energy Authority for processing uranium. For casting large single ingots bottom pouring provides a useful alternative to lip pouring. Basically the technique consists of sealing the pouring orifice with a plug of metal kept solid by a heavily water cooled copper stopper. When the stopper is removed, the solid plug melts and the charge is poured.

The pumping system provided comprises two model 1604 vapour diffusion pumps backed by a model 9B1 vapour booster pump, all in parallel with a model 30B4 vapour booster pump, the vapour pumps being backed by a 310 ft^3/min rotary pump. The complete system provides high pumping speeds from atmosphere to 5×10^{-7} torr.

EDWARDS HIGH VACUUM LTD · MANOR ROYAL · CRAWLEY · SUSSEX · ENGLAND · *Crawley 1500*

Circle **No 15** on reply card for further details





M & C Nuclear — Largest Producer of Co-extruded Fuel

No idle claim this — M&C Nuclear has fabricated more clad pins, plates, wire, rod and tubing by this technique than any other supplier.

Three complete reactor loadings of co-extruded elements made by M&C Nuclear are in operation — and two additional loadings are now being made as a *re-order*.

Until recently, elements clad by co-extrusion were laboratory curiosities — now at M&C Nuclear they are being manufactured on a *production basis*.

We co-extrude tubular uranium aluminum elements of the CP-5 type; plate type cermet elements; alloy elements of uranium with zirconium, niobium and molybdenum as pins, tubes or rods. We can offer wire fuel elements up to 50 feet in length.

The advanced state of co-extrusion technology at M&C Nuclear enables us to offer a high degree of dimensional control, reproducibility, and quality assurance. Complete facilities are available for testing and certification by destructive and non-destructive techniques.

It might well be of importance for you to consider this at an early stage of your next reactor project.

TEXAS INSTRUMENTS
INCORPORATED
M&C NUCLEAR, INC.
(A SUBSIDIARY)
P. O. BOX 898 • ATTLEBORO, MASSACHUSETTS, U. S. A.

Circle **No 16** on reply card for further details

A V.I.P. certainly, not present in person but very much in spirit. A man whom the other three have probably never met and may not even know. A man who is mostly out of sight but never, never out of mind. THEY are the Acheson heads of Sales, Production and Research. HE is a customer—you, perhaps—and at this conference the man of the moment. He knows us well, otherwise he would not be present (spiritually). He knows us well, yet almost certainly not well enough. He may not realise how much more we are prepared to do to help him. He knows we were the first and are the foremost manufacturers of colloidal graphite and MoS_2. He knows of "Oildag" colloidal graphite in oil and "Aquadag" colloidal graphite in water. But does he know about the scores of other Acheson dispersions, of silver, lead and boron, for instance, or vermiculite, glass and mica? Does he know that we have tailor-made, to the most stringent specifications, special dispersions for the UKAEA, Government and Service departments, and many world-famous industrial concerns? If he *does* know these things we apologise for this reminder. If he doesn't, we'll leave one final point with him: there's more in the Acheson service than meets the (regular or potential) customer's eye. Naturally we would be delighted to tell him about it.

Acheson Colloids LIMITED

(a subsidiary of Acheson Industries (Europe) Limited)

50 YEARS

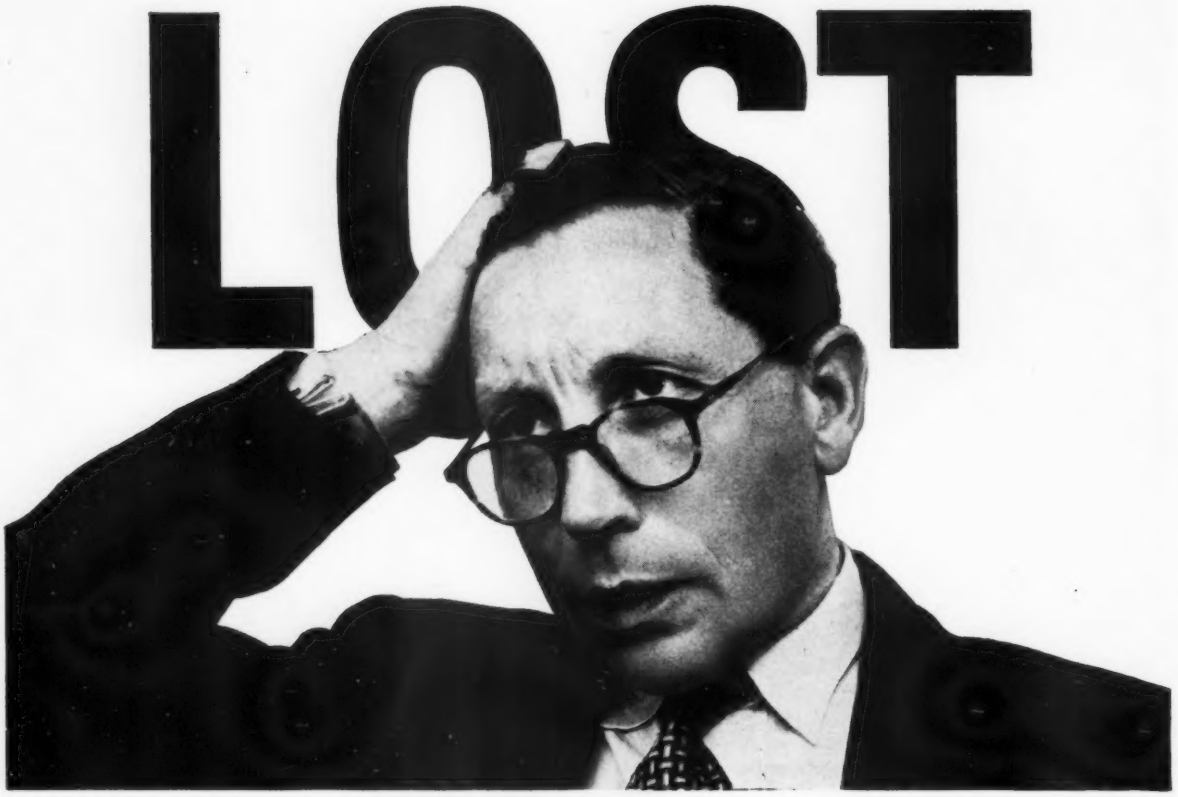
Oildag' and Aquadag' are registered trade marks.

ACHESON

P.O. BOX No. 12 · PRINCE ROCK · PLYMOUTH · DEVON

Also Acheson Colloids Company, Port Huron, Michigan, U.S.A. and Acheson Colloiden N.V. Scheemda (Gr.) Netherlands

LOST



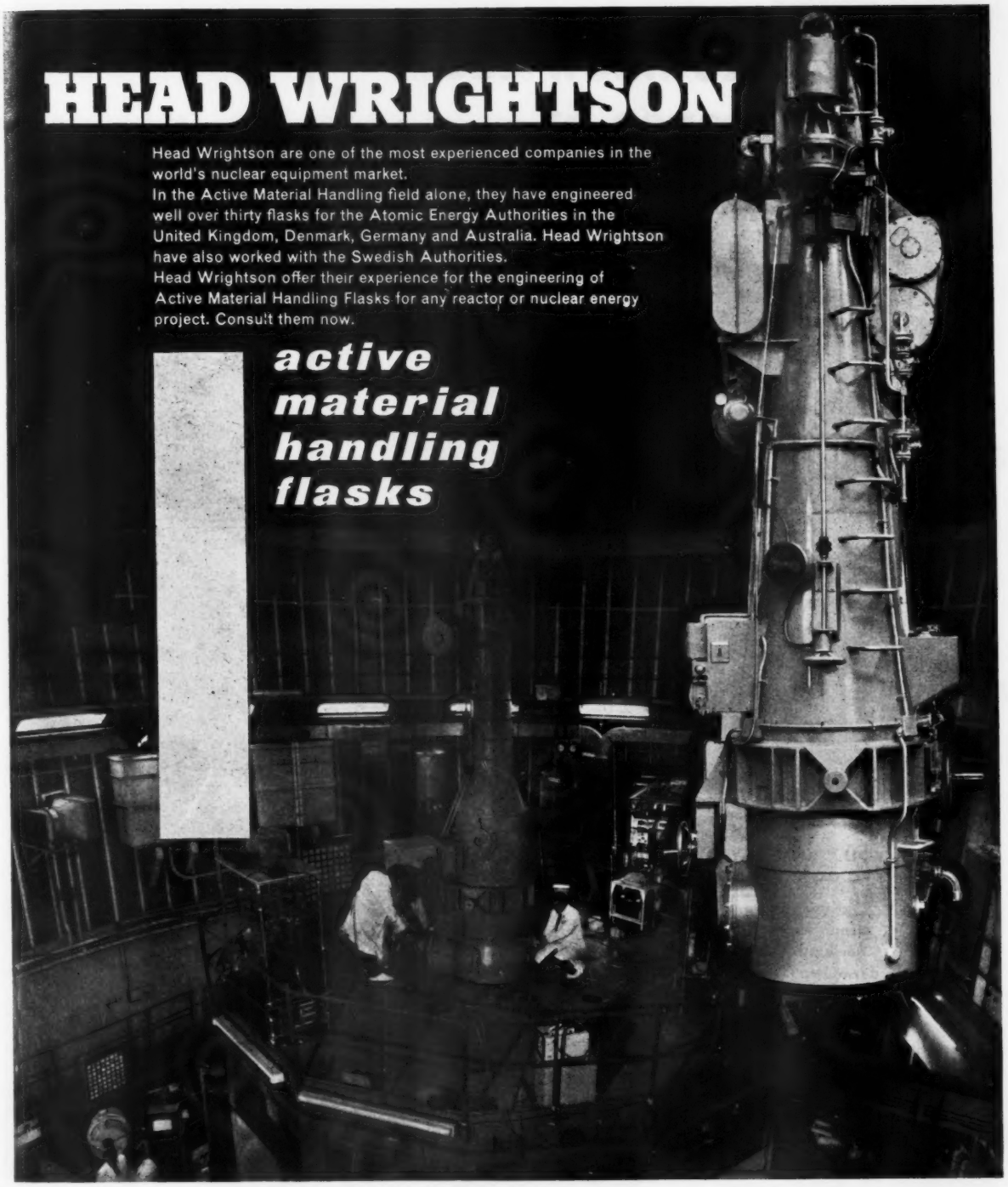
On or about April 1st this year, between Lombard Street and the Metropolitan Police Boundary, a large quantity of Treasury Notes, Bonds, Sleep, Hope etc. by a Firm who forgot that **ASSOCIATED LEAD** supply: **LEAD, TIN, ANTIMONY AND THEIR ALLOYS; 99.999% PURE LEAD, TIN AND ANTIMONY; SOLDERS; ANTIFRICTION MATERIALS; ANTIMONIAL LEAD; CABLE ALLOYS; LEAD SHEET AND PIPE; DENSE LEAD SHIELDING FOR NUCLEAR WORK** as well as every other form of Lead and Antimony, in any quantity. Firm concerned prefers to remain anonymous.

This announcement is issued for and on behalf of

ASSOCIATED LEAD MANUFACTURERS LIMITED

CLEMENTS HOUSE, 14 GRESHAM STREET, LONDON, E.C.2. CRESCENT HOUSE, NEWCASTLE. LEAD WORKS LANE, CHESTER.

Export Enquiries to: Associated Lead Manufacturers Export Co Ltd., Clements House, 14 Gresham Street London, E.C.2


HEAD WRIGHTSON
Head Wrightson are one of the most experienced companies in the world's nuclear equipment market.
In the Active Material Handling field alone, they have engineered well over thirty flasks for the Atomic Energy Authorities in the United Kingdom, Denmark, Germany and Australia. Head Wrightson have also worked with the Swedish Authorities.
Head Wrightson offer their experience for the engineering of Active Material Handling Flasks for any reactor or nuclear energy project. Consult them now.
active material handling flasks

HEAD WRIGHTSON PROCESSES LTD

NUCLEAR EQUIPMENT DIVISION

London Sales Office: 20-24 OLD STREET EC1 **And at: THE FRIARAGE YARM-ON-TEES YORKS**

P5166

Get to know the range of STC COMPONENTS

Write or telephone for booklet (M/103)

YOU CAN RELY ON STC COMPONENTS

Brimistors
Capacitors · Ferrites
Germanium Diodes
Germanium Photocells
Hermetic Seals
High Stability Resistors
Magnetic Materials
Quartz Crystals
Special Valves
Selenium Rectifiers
Silicon Rectifiers
Silistors · Suppressors
Transistors · Thermistors
Tunnel Diodes
Transformers · Zener Diodes

STC COMPONENTS GROUP

60/4M

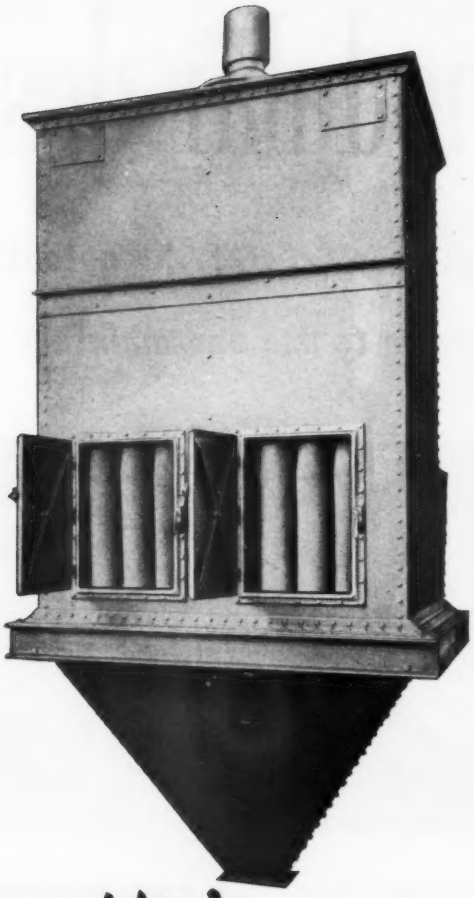
Standard Telephones and Cables Limited

Registered Office: Connaught House, Aldwych, London W.C.2.

COMPONENTS GROUP · FOOTSCRAY · SIDCUP · KENT

FOOTSCRAY 3333 EXTENSION 322

Circle **No 20** on reply card for further details



The Tornado-Fischer automatic, self-cleaning filter handles continuously, with negligible maintenance or attention, dust particles of all sizes.

when the problem's

DUST OR FUMES

turn to 'Tornado'

For over 60 years, Industry has turned to 'Tornado' to settle dust and fume extraction problems. Keith Blackman were the first in the country to use air extraction as the basis for dust and fume exhaust systems. With this record and this experience they are the natural choice for your problem. You too, should 'turn to Tornado' for advice on *complete plants* or individual equipment. There is a qualified representative in every industrial area.

Keith Blackman Ltd

Dust and Fume Control Division

MILL MEAD ROAD. LONDON N.17 TOTTENHAM 4522

TA 3691/1062

CLOTH FILTRATION

Tornado-Fischer patented, self-cleaning filters

Type 270/540 pocket filters

Series TF dust collectors

Series T self-contained dust collectors

WET FILTRATION

Solivore patented wet scrubbers

Hydro precipitator wet washers

CENTRIFUGAL FILTRATION

Cyclogal high efficiency, low resistance cyclones

Cyclogalax 'straight through' cyclones

Standard cyclones

PD-KB tubular collectors

ELECTROSTATIC PRECIPITATION

PD-KB electrostatic precipitators

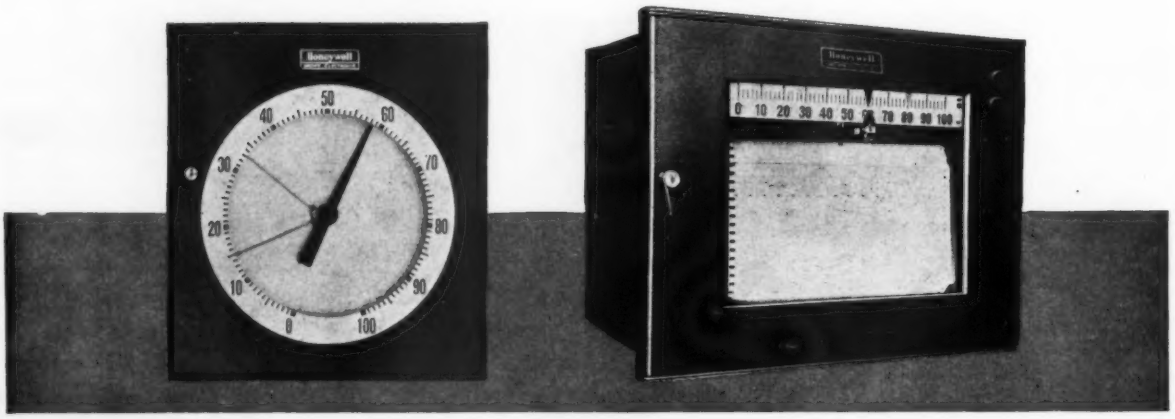
FANS

Paddle type industrial fans

New modular design...

makes ElectroniK potentiometers

easier to use and maintain



Now, four great new features add new operating and servicing ease to all ElectroniK circular and strip chart potentiometers.

1 **New balancing and chart drive motors are sectionalized so that any major part can be replaced in two minutes.**

2 **A new constant voltage unit replaces batteries, standard cells and standardizing mechanisms.**

3 **A new measuring circuit, with quick-change range spools, simplifies range changing and reduces stray pickup.**

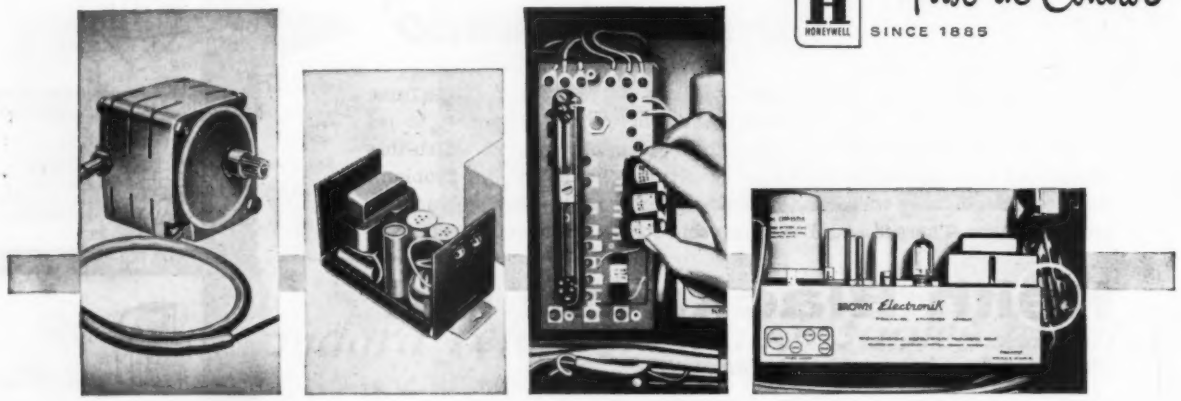
4 **A quick-connect feature permits removal of amplifier for service and its quick replacement.**

Now, modular design is combined with the traditional precision of ElectroniK potentiometers, to give you a greater value than ever in accurate, dependable measurement and control.

For full details write to Honeywell Controls Ltd, Ruislip Road East, Greenford, Middlesex. WAXlow 2333.

Honeywell

H HONEYWELL *First in Control* SINCE 1885



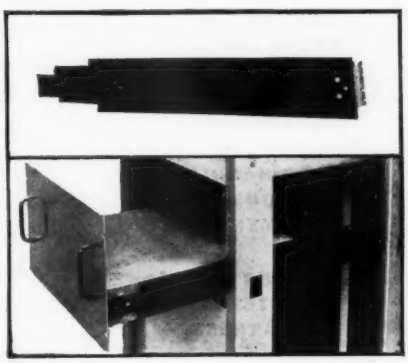
1 Balancing Motor 2 Constant Voltage Module 3 Measuring Circuit Module 4 Amplifier Module

Here a pair of Imslides (IMS 500/19) are shown carrying well over 300 lb. (135 kg.): the Imslide Technical Service will be pleased to give recommendations wherever loads of this order are proposed

IMslide

a new approach to telescopic runner design - *combines all the features*

Imhofs new telescopic mountings are introduced to meet the specific needs of the electronics industry. They combine lightness, maximum strength, lowest possible friction characteristics under full load and minimum overall thickness—yet they are reasonably priced. Imslides are manufactured at our Uxbridge works from high tensile strength aluminium alloy with a black anodised finish. The new runners weigh only 6½ lb. per pair against 18 lb. for a pair of conventional runners and are only ¼" thick overall. Imslides are ready pierced with countersunk holes for fixing to certain types of rack mounting; special Imslide brackets are available which considerably extend the variety of rack mountings and give adjustment on height. Imslides are also pierced for attaching the chassis itself. Write for leaflet and details of latest light-duty Imslide



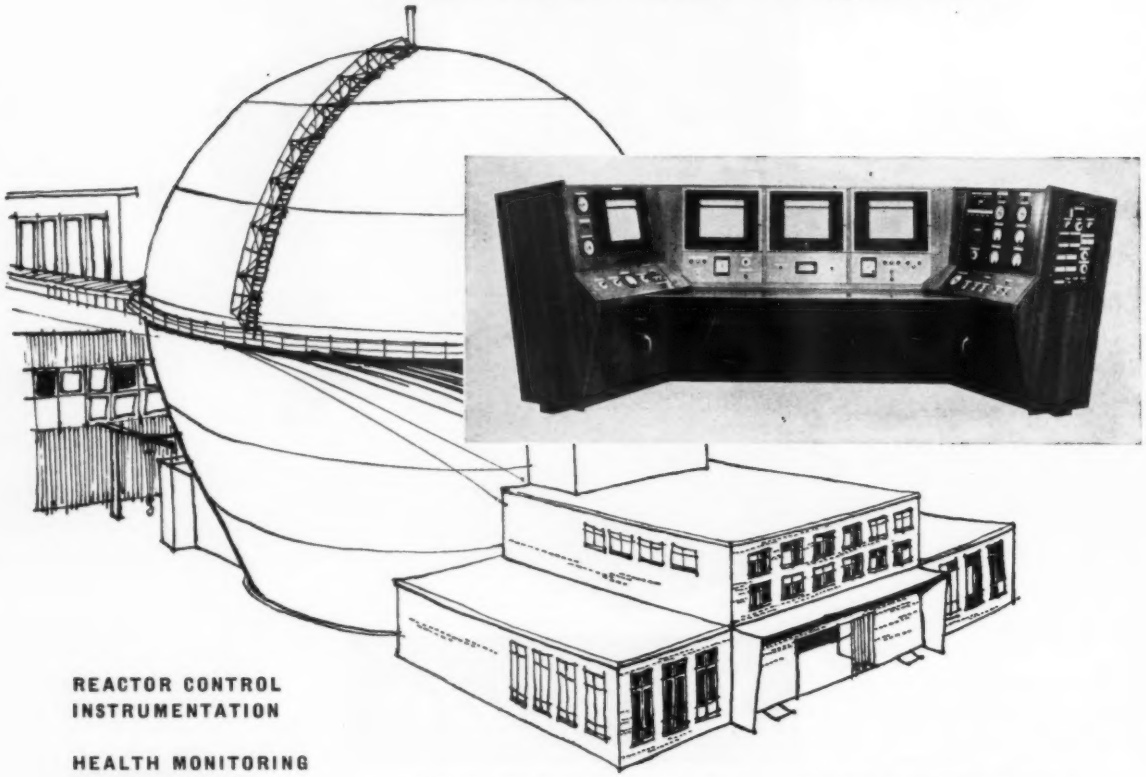
Alfred Imhof Ltd. Dept. N 9 **Ashley Works, Cowley Mill Road, Uxbridge, Middx.** *Uxbridge 37123*

London Showrooms: 112-116 New Oxford Street, W.C.I. *MUSeum 7878*

IMHOFS AGENTS OVERSEAS

Algeria: E.G.E.E., Paris (19)
Australia: Aladdin Industries (Pty) Ltd, Stanmore NSW
Belgium: Rogelec, Ghent
Canada: Measurement Engineering Ltd, Arnprior
Denmark: Tage Schouboe, Copenhagen N
Finland: Oy Scienta Ab., Helsinki
France: E.G.E.E., Paris (19)
Germany: Sunvic Regler GMBH Solingen—Ohligs
Holland: J. Th. van Reijsen, Delft
Italy: Stuart Culley, Milan
Mexico: Alumino Arquitectonico, S.A. Mexico D.F.
Morocco: E.G.E.E., Paris (19)
New Zealand: Imarex Ltd, Auckland C3
Norway: Birger Christensen, Oslo
Portugal: Projectos e Construçoes Lda, Lisbon
South Africa: Switchcraft (Pty) Ltd, Johannesburg
Sweden: Electronlund AB, Malmo C
Switzerland: Walter Blum, Zurich 2/39
Tunisia: E.G.E.E., Paris (19)
U.S.A.: Bud Radio Inc, Cleveland 3, Ohio
British Guiana: Davsons Caribbean Agencies Ltd, Georgetown

What ELLIOTT nucleonics LIMITED means to the nuclear engineer



REACTOR CONTROL INSTRUMENTATION

HEALTH MONITORING EQUIPMENT AND ADVISORY SERVICE

CONTROL ROD MECHANISMS

PROCESS CONTROL INSTRUMENTS

DATA HANDLING AND COMPUTING EQUIPMENT

REACTOR ANALOGUE COMPUTERS AND SIMULATORS

FLUX SCANNING EQUIPMENT

Elliott Nucleonics Ltd., offers to the Nuclear Engineer a complete instrument and system engineering facility.

Examples of this Company's work may be seen at all of the civil Nuclear Power Stations under construction in this country, and have included such contracts as the REACTOR SIMULATOR, designed and manufactured for the Central Electrical Generating Board, now installed at Berkeley Power Station and the complete instrumentation of the NEPTUNE Zero Energy Reactor at Harwell.

We are actively engaged on the development of control instrumentation for the "DREADNOUGHT" project, the Control Rod Mechanisms for A.G.R. Flux Scanning equipment for HERO and also for the TRAWSFYNYDD Nuclear Power Station.

An example of the Company's forward thinking policy was the introduction recently of a complete range of Transistorised Reactor Control Instruments.

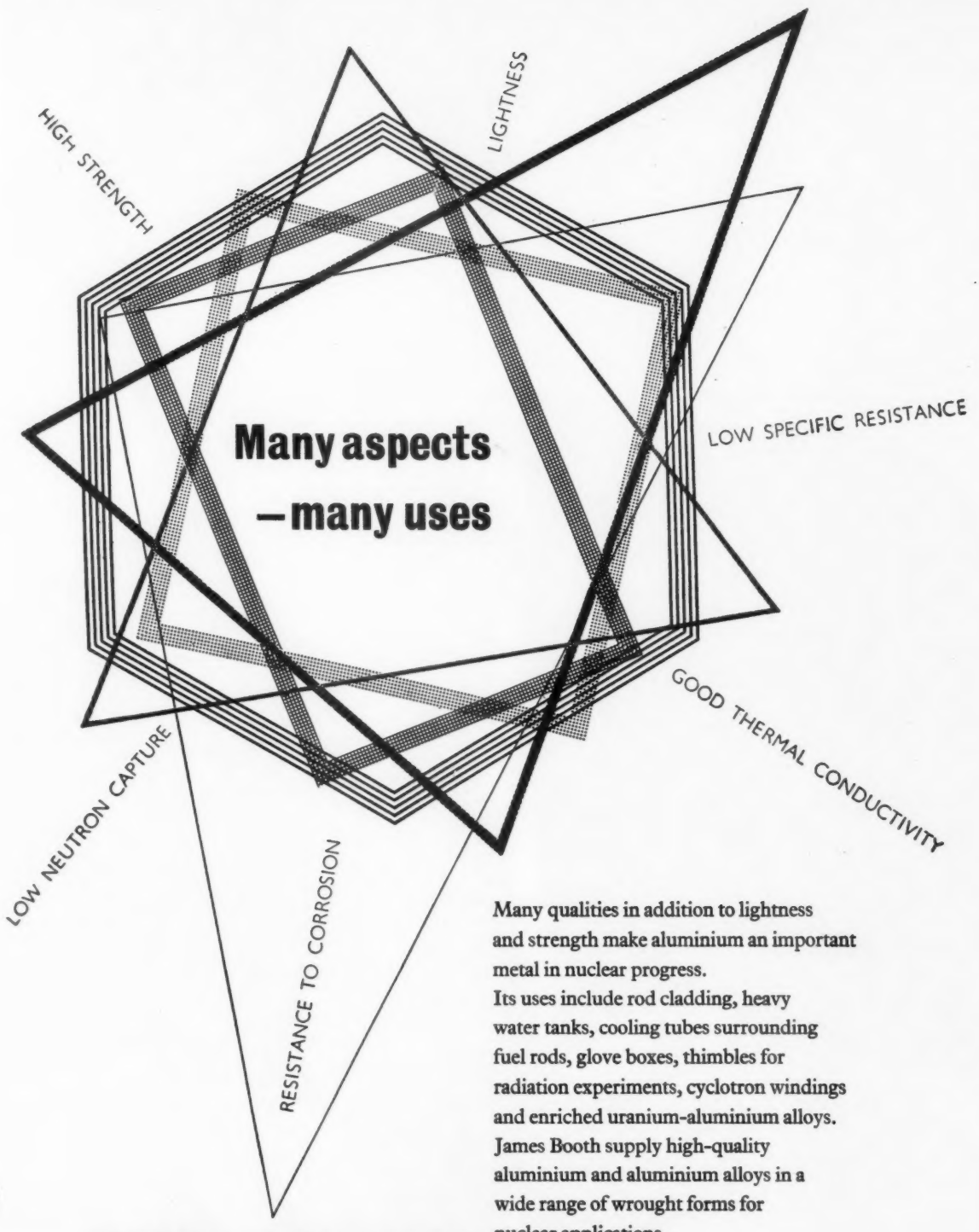
ELLIOTT NUCLEONICS CAN HELP YOU

ELLIOTT nucleonics LIMITED

Century Works, London S.E.13 ***Telephone: TIDeway 1271***

A MEMBER OF THE ELLIOTT-AUTOMATION GROUP

EN2

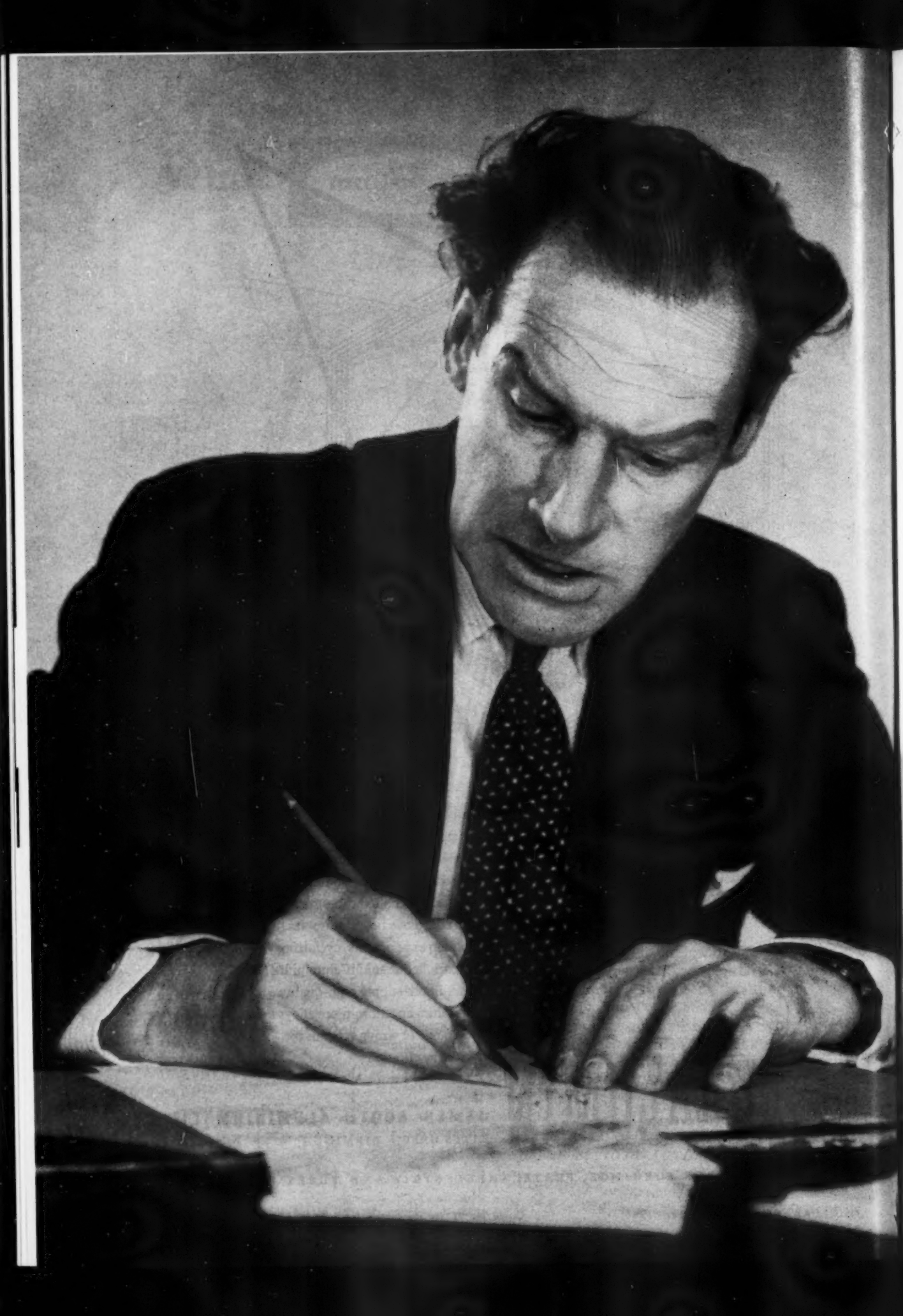


Many qualities in addition to lightness and strength make aluminium an important metal in nuclear progress.
Its uses include rod cladding, heavy water tanks, cooling tubes surrounding fuel rods, glove boxes, thimbles for radiation experiments, cyclotron windings and enriched uranium-aluminium alloys.
James Booth supply high-quality aluminium and aluminium alloys in a wide range of wrought forms for nuclear applications.

DURALUMIN
REGD. TRADE MARK

JAMES BOOTH ALUMINIUM LIMITED
KITTS GREEN, BIRMINGHAM 33. *Tel: Stechford 4020*

EXTRUSIONS, LARGE FORGINGS, PLATE, SHEET, STRIP AND TUBES IN LIGHT ALLOYS
TGA/1BG179



Dear Sir,

Why have you the exasperating habit of . . .

Nuclear Power editorial department is largely staffed with scientist-journalists, but this does not mean that we are interested only in technical matters.

We write with pleasure about people's triumphs and report their comings and goings. We also enjoy reading and answering the many letters we receive from readers.

Most of these letters are about technical subjects and are, so to speak, neutral in tone. Many are complimentary. Some are critical. A few are penned in the strongest terms.

We print some. We welcome and take note of them all.

When a reader pays us the compliment of taking the trouble to write it behoves us to sit up and take notice.

Corresponding and so-far-non-corresponding readers are reminded that renewals of subscriptions sent, say, two months in advance help us to keep up more accurately with our growing print demands.

AIRMEC

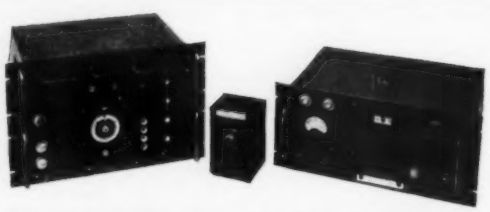
MONITORS

FOR BENCH OR FIELD USE

TYPE 255

- **PORTABLE**
  Transistorised, battery operated, weighs only 16 lbs with batteries
- **ACCURATE**
  Laboratory accuracy under field conditions. Accuracy of measurement generally better than ± 2·5%, which is not affected by falling battery voltage
- **VERSATILE**
  Wide range of probes and accessories available, including Alpha, Beta Gamma, End Window and Liquid sample probes, a Sample Holder and a Lead Castle. A stout leather case is available for carrying the probes.

WRITE FOR DESCRIPTIVE LEAFLET No. 177B



GENERAL PURPOSE COUNTER TYPE 1339A

TYPE 1021B

- **SAFEGUARDS** against contamination
- **TRACES** radio-active material in chemical analytic processes
- **MEASURES** radio-active material in chemical

Designed in conjunction with A.E.R.E. Harwell, this instrument is probably the most widely used general purpose monitor in the world. It has been PROVED by years of user experience to be the most accurate and reliable equipment of its type. The Radiation Monitor consists of a mains operated Indicator Unit together with a Beta Gamma or Alpha Probe Unit. Indication is provided visually by means of a meter which is calibrated in counts per second, and audibly by means of a loudspeaker. A socket on the front panel is also provided to enable the output to be fed to a scaling unit.

WRITE FOR DESCRIPTIVE LEAFLET No. 26D

AND A SCALER FOR THE LABORATORY

- Provides comprehensive scaling facilities for all types of Geiger Scintillation Counters
- Incorporates stabilised E.H.T. Supplies
- Fitted with automatic timing control
- Designed and developed in conjunction with U.K.A.E.R.E.

WRITE FOR DESCRIPTIVE LEAFLET No. 185

Airmec

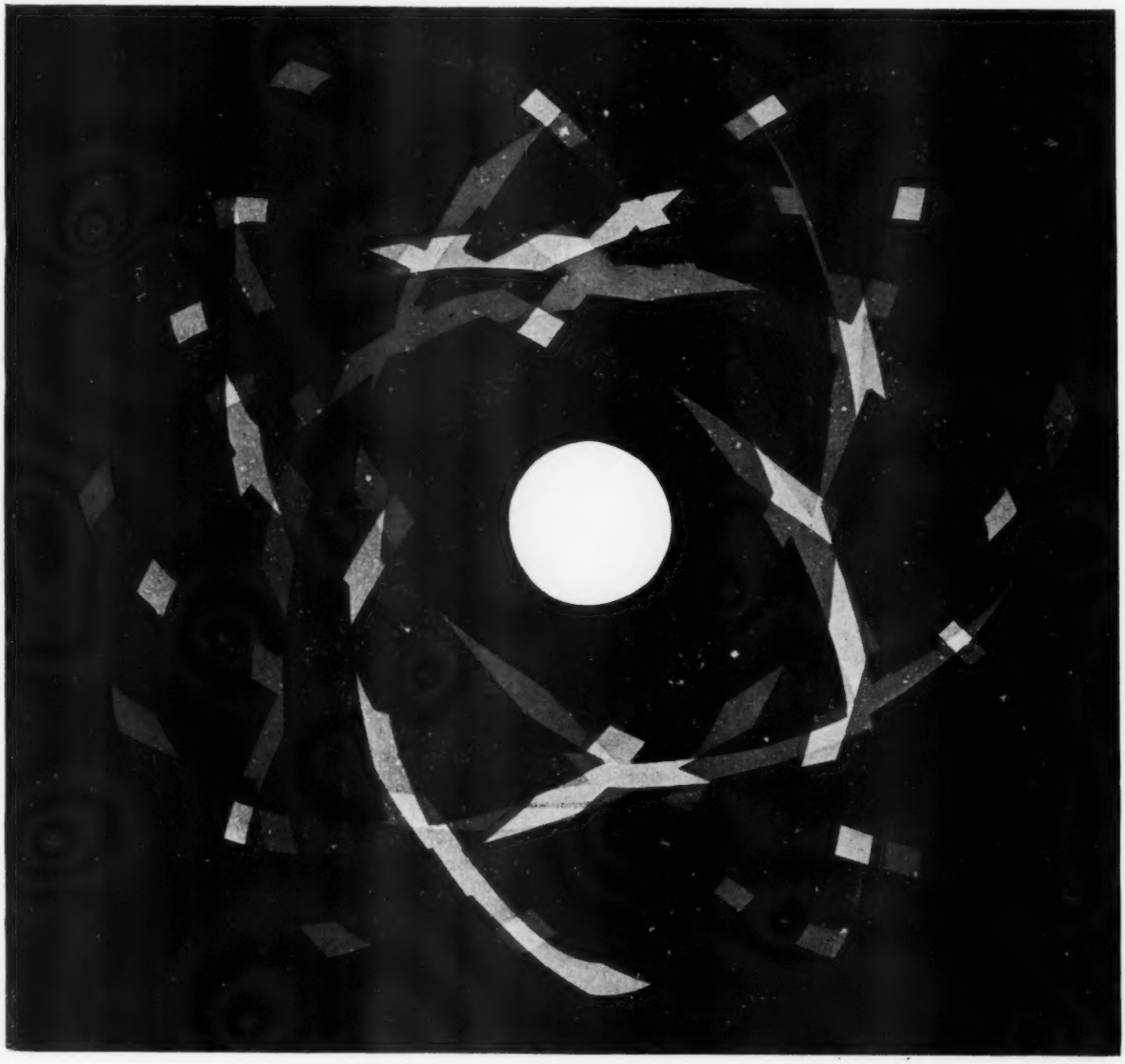
Instruments for the Nucleonic Age

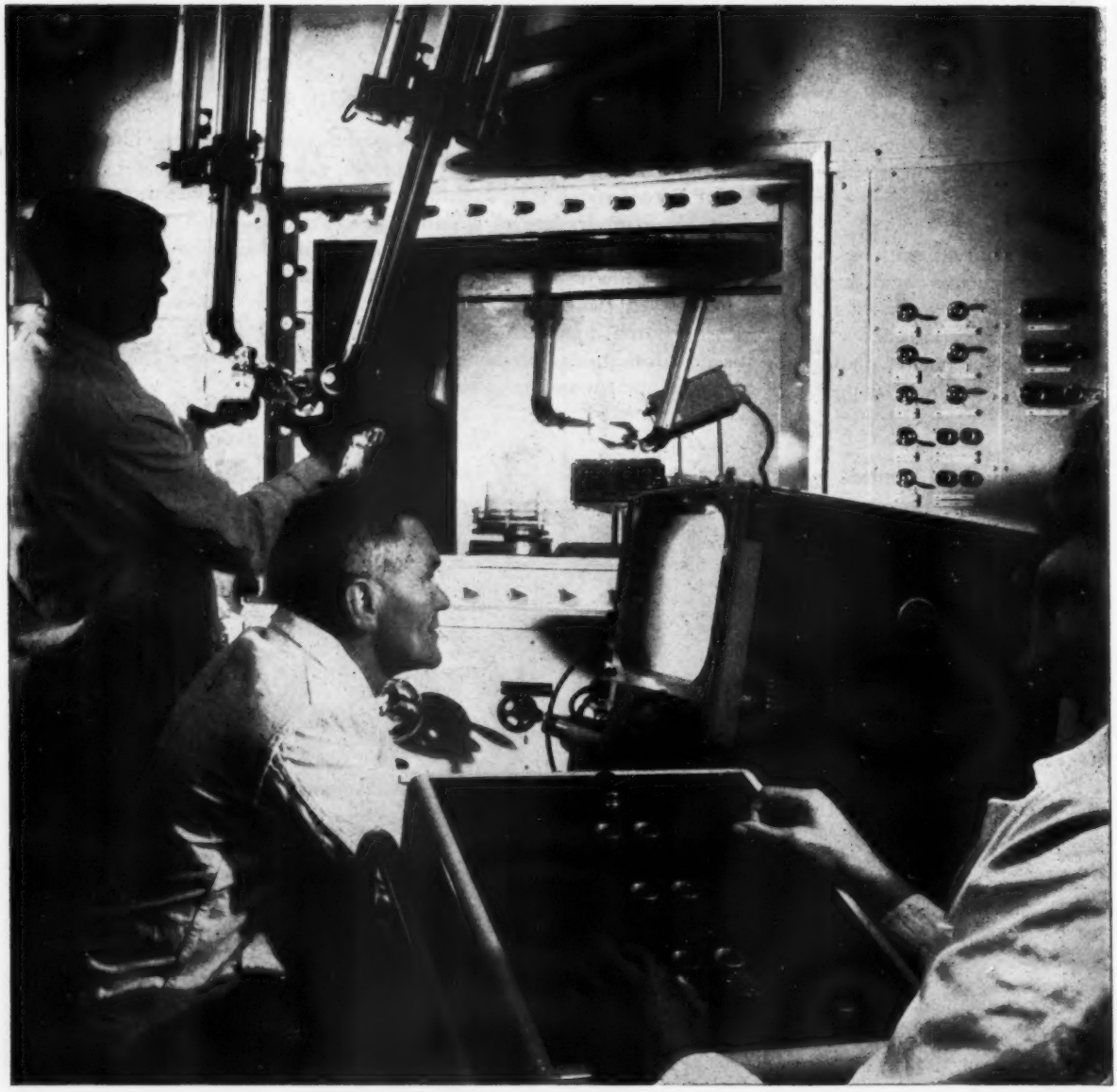
AIRMEC LIMITED · HIGH WYCOMBE · BUCKS · Tel: High Wycombe 2501-7

ATOMIC FAIREY

What are Fairey's doing in Atomics? What aren't they? Aluminium and steel fabrications, charge machines, control mechanisms, graphite machining and laying, irradiated fuel disposal equipment, gas filtration . . .
At Britain's latest nuclear power station at Trawsfynydd, as in so many other projects, Fairey are there . . . at the heart of things. They are at work on a major programme of research, development, design and manufacture for nuclear power stations and experimental establishments throughout the country. Fairey have been thinking and living nuclear engineering for years—they know what they're about.
Fairey's nuclear work includes: U.K.A.E.A. experimental reactor equipment, power reactor equipment, fuel element cans, controlled thermonuclear research equipment, aluminium and steel fabrications nuclear fuel processing equipment, plastics and plastics fabrications, electronics and special instrumentation, machine tools and remote handling equipment, hydraulic equipment and gas filters.

Fairey Engineering Limited Heston · Middlesex Stockport · Cheshire *(A member of The Fairey Group of Companies)*





Pye at Dounreay

The Pye Instrument Group has supplied all the equipment to the U.K. Atomic Energy Authority for the irradiated fuel element laboratory at Dounreay. In addition to supplying equipment, Pye Ltd. acted as consultants and designers on all matters in that laboratory relating to instrumentation and remote handling. The illustration above shows manipulators working in conjunction with a television camera to handle and measure a sample from the fast reactor.

The Pye Instrument Group consists of: Pye Atomics Division; Pye Industrial Television Division; Faraday Electronic Instruments Ltd.; Labgear Ltd.; W. G. Pye & Co. Ltd.; Pye Telecommunications Ltd.; Unicam Instruments Ltd.; W. Bryan Savage Ltd.; W. Watson & Sons Ltd.

AVO INSTRUMENTATION

Pioneers in the design and manufacture of Multi-range Testing Instruments since 1923

AVO instruments are in the service of B.O.A.C. throughout the world

D.C. Amplifiers
Radiation Monitors
Valve Voltmeters
Multi-range Testmeters
Valve Testers
and other electronic and nucleonic instruments

AVO LTD

AVOCET HOUSE · 92-96 VAUXHALL BRIDGE ROAD · LONDON · S.W.1

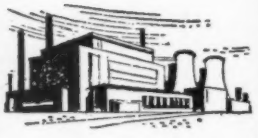
Telephone: VICtoria 3404 (12 lines) *Cables: Avocet, Sowest, London*

A member of the Metal Industries Group of Companies

G21

THERMAL INSULATION BY Newalls

Throughout the years Newalls have built an enviable reputation in the insulation of conventional power stations. This specialised experience is now being drawn upon on an ever growing scale in solving the complex problems of Nuclear Power Development. Recent contracts in this field reflecting Newalls supremacy are:—



HINKLEY POINT

C.E.G.B. NUCLEAR POWER STATION

At Hinkley Point, Newalls have been entrusted with the insulation of the reactors, steam raising units, gas ducting integral piping, etc., under contract to Babcock and Wilcox Ltd

CHAPELCROSS

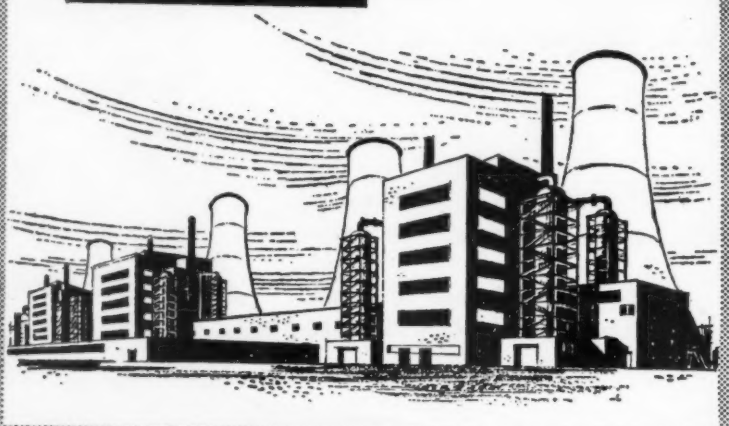
U.K.A.E.A. NUCLEAR POWER STATION

Under contract to Babcock and Wilcox Ltd., Newalls have carried out the insulation of the 16 steam raising units and integral piping. The insulation of turbines, blowers, associated auxiliary equipment and piping has been carried out under contract to C. A. Parsons and Co. Ltd.

BRADWELL

C.E.G.B. NUCLEAR POWER STATION

At Bradwell-on-Sea a further large contract for the thermal insulation of turbines, associated auxiliary equipment and piping (main and auxiliary turbine plants) has also been placed by C. A. Parsons and Co. Ltd. with Newalls.



NEWALLS INSULATION COMPANY LIMITED

Head Office:

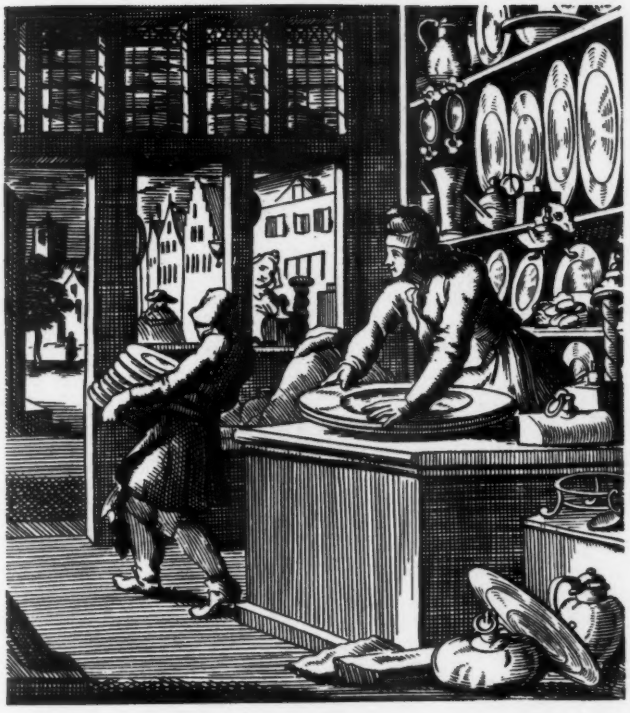
WASHINGTON, CO. DURHAM.
A member of the TURNER & NEWALL ORGANISATION.

Offices and Depots at:

LONDON, GLASGOW, MANCHESTER, NEWCASTLE UPON TYNE, BIRMINGHAM, BELFAST, DUBLIN, BRISTOL and CARDIFF Agents and Vendors in most markets abroad.

74

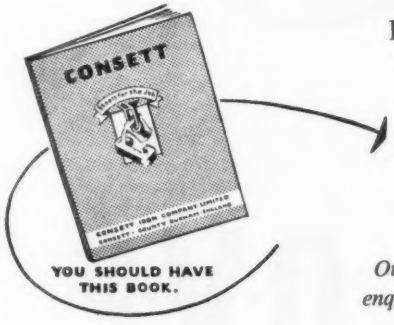
Reproduction of 16th century Dutch Print, illustrating the craft of the Tin-smith. (Copyright, Radio Times—Hulton Picture Library)



Every man to his own trade—

and our trade is STEEL!

Not only mild steel for everyday use but also the special steels demanded by the Nuclear Age . . . for example we produced the special steel plates for the reactor vessels at Calder Hall, Chapelcross and Bradwell, and have now supplied plates for the nuclear power station reactor at Latina, Italy.



An interesting booklet "Steels for the Job", just published by us, describes some of our newer products. We shall be delighted to send you a copy.

Our Technical and Research Department will also welcome enquiries from any whose problem is . . . **STEEL**

CONSETT IRON COMPANY LIMITED, CONSETT, COUNTY DURHAM

Telephone: Consett 341 (12 lines) Telegrams: Steel Phone Consett

Plant in GLASS For $H.Cl.$ Absorption

QUICKFIT *Visible Flow*

HYDROCHLORIC ACID ABSORPTION UNIT. *(Photo by courtesy of I.C.I. Ltd.)*

The Q.V.F. range of Industrial Plant in Glass provides a satisfactory answer to most of the problems encountered in the field of hydrogen chloride absorption, whether in the manufacture of hydrochloric acid or in the recovery — in usable concentrations — of by-product H Cl.

If your particular problem is:

ATMOSPHERIC POLLUTION
ABSORPTION
BY-PRODUCT RECOVERY
BATCH REACTION
CORROSION
DRYING
GAS GENERATION or
PURE ACID PRODUCTION

there is a range of standard Q.V.F. glass plant —as complete "Packaged Units"—available to meet your special requirements and ready for erection in your works.

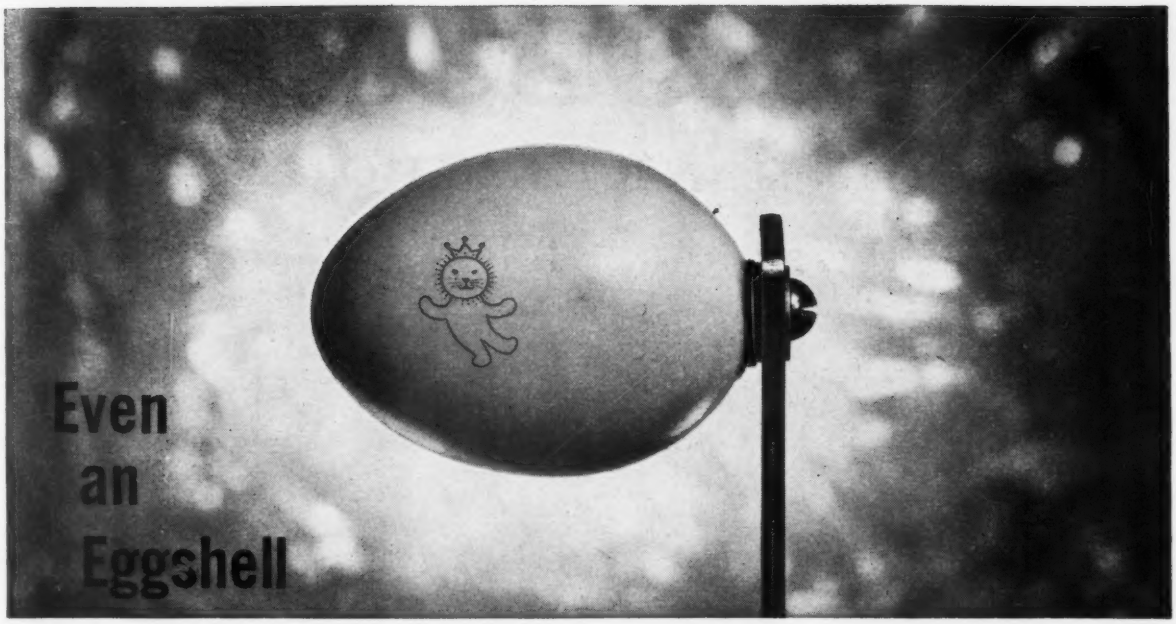
Fully descriptive brochure available on request

DUKE STREET · FENTON · STOKE-ON-TRENT
STAFFORDSHIRE

TEL: LONGTON, STAFFS 32104-8
'GRAMS: Q.V.F., STOKE-ON-TRENT, TELEX

Q·V·F·
LIMITED
The Chemical Engineers in Glass

M.G.P.



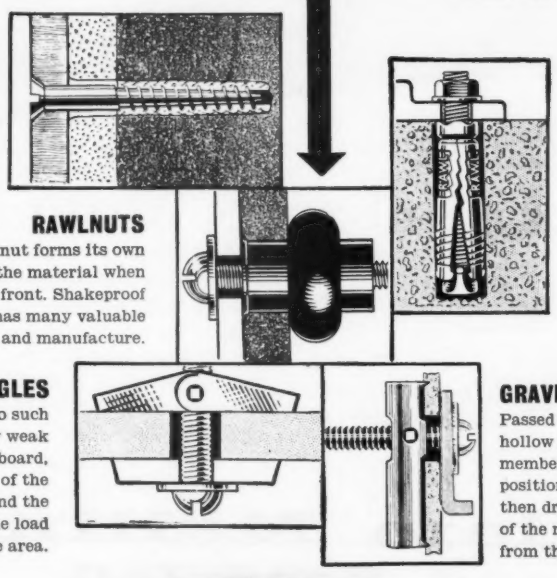
can be Screw-fixed with a RAWLPLUG FIXING DEVICE!

If you live to a hundred, you are unlikely to want to do much screw-fixing of eggshells! Yet this feat—possible only with a Rawlplug Fixing Device (a Rawlnut)—does serve to highlight the astonishing effectiveness of these Devices in making 'difficult' and even 'impossible' fixings simple and straightforward. Whatever the screw or bolt fixing job, you'll save time, money and temper by using the appropriate Rawlplug Fixing Device.

RAWLPLUGS
The famous Rawlplug makes firm screw fixings in masonry in a mere fraction of the time taken by any other method. For all screw sizes up to ⅜" diam. coach screws.

RAWLNUTS
The amazing Rawlnut forms its own 'rivet head' behind the material when screwed up from the front. Shakeproof and waterproof, it has many valuable uses in both building and manufacture.

SPRING TOGGLES
For making firm fixings to such thin and structurally weak materials as plasterboard, ceilings, etc. The wings of the device spring apart behind the material and spread the load over a wide area.



RAWLBOLTS
For light or heavy bolting jobs. A dry fixing of enormous strength—no cold chiselling, no waiting for cement to harden. In all bolt diameters up to 1".

GRAVITY TOGGLES
Passed through a hole in hollow material, the long member falls into a vertical position by gravity, and is then drawn against the back of the material by screwing from the front.

IMPOSSIBLE FIXINGS ARE EASY WITH

RAWLPLUG WALL PLUGS

FIXING DEVICES *For Speed and Strength!*

The World's largest manufacturers of fixing devices

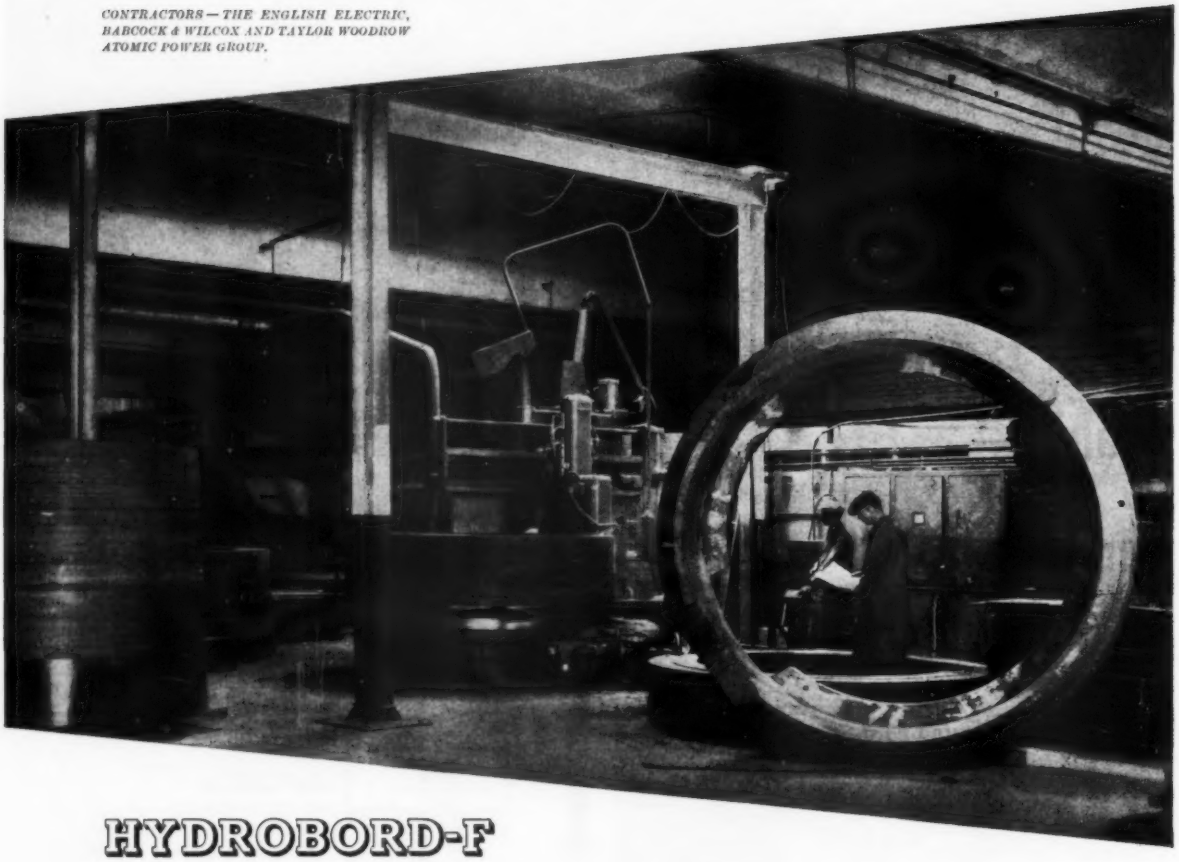
THE RAWLPLUG COMPANY LTD., CROMWELL RD., LONDON S.W.7

B669

HYDROBORD-F

FOR HINKLEY POINT

CONTRACTORS—THE ENGLISH ELECTRIC, BABCOCK & WILCOX AND TAYLOR WOODROW ATOMIC POWER GROUP.



HYDROBORD-F

FOR FAST NEUTRON SHIELDING

The 9′ 3½″ diameter annular sections being machined are part of the Hydrobord-F Shielding for the 56′ 0″ high Hole Preparation Machine.

Hydrobord-F provides shielding against fast neutrons, Hydrobord-T against thermal neutrons and Hydrobord-FT against both as required.

William Mallinson and Sons Ltd.

TIMBER AND VENEER MERCHANTS

130 HACKNEY ROAD · LONDON · E.2

Telephone: Shoreditch 7654 Telegrams: Almoner, London

MANUFACTURERS OF PLYWOOD · ARMOURPLY · PANELS AND COMPOSITE PARTITIONING

FINE-GRAIN even at X20

Mr. G. B. Higgins, Chief Radiologist in the Public Test House of Vickers-Armstrongs (Aircraft) Limited was asked by a customer* to examine batches of mineral-insulated thermocouple wires obtained from various suppliers for use in nuclear reactor test rigs. He was asked to compare the wires for thickness of sheath, thickness of conductors, and concentricity of conductors inside the sheath.

The materials were a few thousands of an inch thick (the largest wire being only 1/16th-inch in diameter) so it would be necessary to project magnified images of the radiographs on to a screen. A film with very high contrast and the finest possible definition was necessary, so Mr. Higgins chose 'Industrex' film Type M.

The technique was to use low-kilovoltage X-rays at a large film-focal distance. Firm contact was maintained between wire and film, and the radiograph was slightly under-exposed to avoid the chance of getting false readings because of undercut.

The radiograph was viewed on a universal gauge projector in Vickers' metrology laboratory at Swindon. All the required information, correct to within 1% of the actual material thickness, was obtained easily at a magnification of X20.

Spot radiography was carried out in this way throughout the 75-foot lengths of thermocouple wire to ensure that the very high standard demanded in nuclear research was maintained.

Where the requirements are for the finest possible resolution with very high contrast there is no better material than Kodak X-ray Film Type M.

*The extensive Test House facilities of Vickers-Armstrongs (Aircraft) Limited are available to users on a commercial basis.

Kodak

'INDUSTREX' X-RAY FILM TYPE M

In previous announcements in this journal we have listed various Kodak publications which describe the many industrial applications of photography and radiography. These publications are free, and appropriate literature will be sent to you with pleasure if you will let us know your particular interests.

Kodak Limited, Industrial Sales Division, Kodak House, Kingsway, London, W.C.2

Circle **No 37** on reply card for further details

TUDOR BATTERIES

A wide range of equipment with a wide range of applications

TUDOR PRODUCTS ARE USED FOR:

Stand-by duties, e.h.t. switchgear operation, emergency and indication lighting in Power Stations (conventional and nuclear) and Sub-stations.
Stand-by duties in telephone exchanges and repeater stations.
D.C. testing in laboratories.
Emergency lighting and emergency duties, clocks and alarms in public buildings and places of entertainment (stores, banks, schools, hospitals, theatres, cinemas, dance halls, swimming baths, village halls).

TO MEET THESE REQUIREMENTS WE SUPPLY:

B.S.S. cells in wooden lead-lined boxes.
B.S.S. cells in open glass boxes.
B.S.S. cells in sealed glass boxes.
High Performance cells in sealed glass boxes.
A complete range of emergency lighting equipments, both self-contained and with the batteries mounted separately.
Self-contained switch-tripping equipments.
All types of chargers and associated switchboards.

Tudor

T176

THE D.P. BATTERY CO. LTD. MAKERS OF KATHANODE AND TUDOR BATTERIES,
BAKEWELL, DERBYSHIRE. BAKEWELL 581-5

ARE YOU AWARE THAT

WESTON

Regd. Trade Mark No. 763106

SPLIT SEALS

CAN BE RE-CONDITIONED AND

USED INDEFINITELY?

CHARLES WESTON & CO. LTD.

Irwell Bank Works, Douglas Green, Pendleton, Salford 6.

Telephone: Pendleton 2857-8-9 Telex: 66-255

Birmingham: Erdington 5459 London: Holborn 0414. Telex: 2-2682

Circle **No 39** on reply card for further details

Greater safety for hands

With new Shell Dromus Oils

Most modern soluble cutting oils contain phenolic compounds used as coupling agents between the oil and the emulsifier, for better blending and easier mixing. These phenolic compounds can cause skin irritation, especially where modern high-speed machines are used and the emulsion can concentrate, through the evaporation of water, above the safety level.

Shell research chemists have been working on this problem, which has been causing some concern to Management. After considerable research, Shell Dromus Oils have been reformulated and these new cutting oils now produce bland emulsions, which considerably reduce the risk of skin trouble to operators.

The real difficulty was to find a new coupling agent to replace the phenolic compounds, and Shell finally used what their chemists know as a higher fatty alcohol complex. This solved one problem, but presented another. The new coupling agent was volatile at the high temperatures normally used in blending processes. Further research found a solution to this problem by designing and installing new plant.

The new Dromus Oils are every bit as efficient as before and cost no more. They put Management in the welcome position of being able to minimise working hazards at no extra cost. And machine men need no longer be so worried about skin troubles.

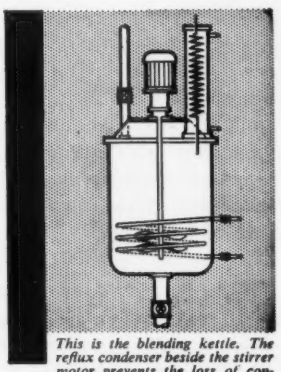
The moral of the story is that Shell research is supremely applicational. The centre at Thornton is always ready to work with even the most specialised sectors of industry to produce the right oil for the job. If you and your organization have any major lubricating problems, it pays to get in touch with your local supplier of Shell Industrial Lubricants.

The Research Story

Shell chemists in the U.K., in Holland and in the U.S.A., prepared and examined hundreds of experimental soluble oils, and established that certain combinations of fatty alcohols could be used in place of phenolic compounds with no loss of efficiency. They set to work to discover the best combination and developed a higher fatty alcohol complex which fitted exactly. Then they realised that to blend this new coupling agent into soluble oils would require special plant and new blending techniques.

Exhaustive testing of blend stability, emulsion stability, anti-corrosion and machining properties led to selection of the most promising blends. A pilot plant was set up to produce batches of these for use in field trials.

This field testing and final development proceeded for two years whilst production plants were erected at points so chosen as to give the most economical and rapid delivery throughout the United Kingdom.



This is the blending kettle. The reflux condenser beside the stirrer motor prevents the loss of constituents volatile at the blending temperature.

NEW SHELL DROMUS SOLUBLE CUTTING OILS

another proof of Shell leadership in lubrication

Circle **No 41** on reply card for further details

'MAREX'

hollow plastic

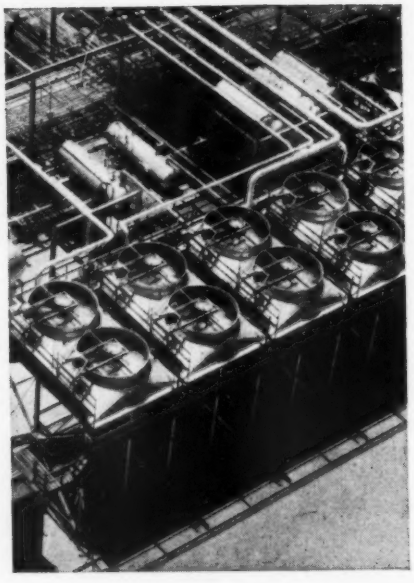
INDUSTRIAL FANS

for oil,

gas and chemical plant,

process cooling

and ventilation



Marston Excelsior Limited have acquired the exclusive right from the Hudson Engineering Corporation of Houston, Texas, to manufacture their 'Tuflite' hollow plastic fan blades and variable-pitch hubs in the U.K.
These fans have shown substantial practical and economic advantages over conventional types in the course of several years of operation under a wide variety of different conditions. Initially available in overall diameter sizes of 6 ft. to 14 ft. in increments of 1 ft.

'Marex' fans are :—
extremely tough—extremely light—highly efficient—corrosion-resistant—shatter proof.

and make for
greater safety—easy installation—minimum maintenance.

Enquiries to

MARSTON EXCELSIOR LIMITED
(A subsidiary company of Imperial Chemical Industries Limited.)
Fordhouses, Wolverhampton.

MAR 274

Circle **No 42** on reply card for further details

HIGH EFFICIENCY PIPE INSULATION DATA

MINUS 400° F

to **PLUS** 1500° F

STILAG

PREFORMED MINERAL WOOL PIPE INSULATING SECTIONS

Technical Data Leaflet No. 7 contains useful tables of recommended thicknesses of STILAG insulation for various pipe sizes over a range of temperatures together with relevant 'K' values, heat losses and surface temperatures. Please send the coupon for your copy.

To: STILLITE PRODUCTS LTD. 15 Whitehall, London, S.W.1

Please send me Technical Data Leaflet No. 7.

NAME.....

ADDRESS .....

.....

Just attach this coupon to your letterhead. *Nuclear Power*

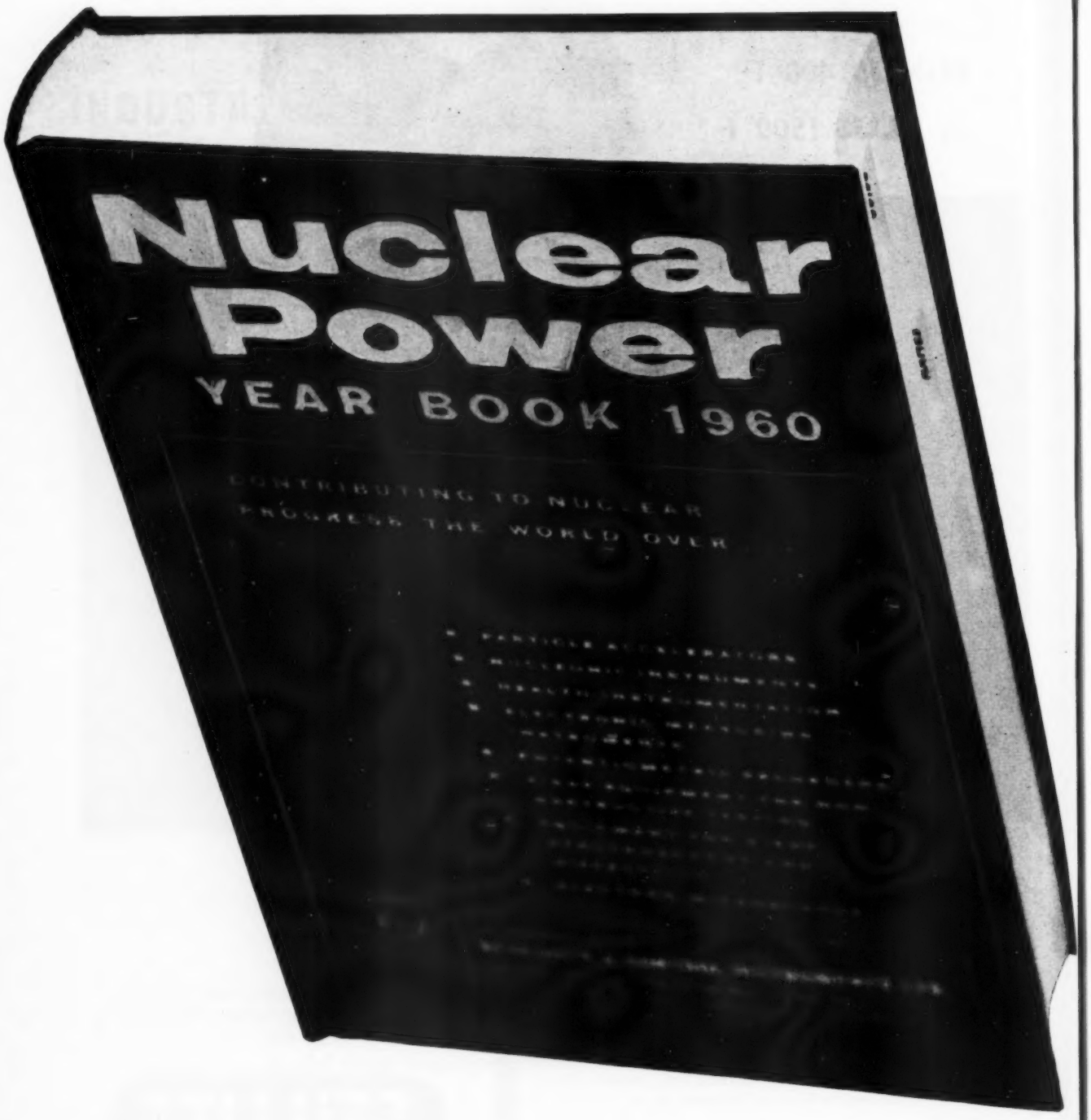
STILLITE

Regd. Trade Mark

STILLITE PRODUCTS LTD.

15 Whitehall, London, S.W.1. Tel: WHitehall 0922/7

231 St. Vincent Street, Glasgow, C.2. Tel: Central 4292


Nuclear
Power
YEAR BOOK 1960
CONTRIBUTING TO NUCLEAR
PROGRESS THE WORLD OVER

THE 1960 NUCLEAR POWER YEAR BOOK & BUYERS' GUIDE

NOW IN ITS 3rd EDITION

the Nuclear Power Year Book and Buyers' Guide is the only comprehensive publication of its kind in the world

CONTENTS

1 1960 Review
An uptodate critical review of the British nuclear power scene, details of the British nuclear contracting groups and the electricity generating authorities, data on British reactors, map of nuclear energy establishments and power stations.

2 World Authorities
The history, organization and plans of all national atomic energy authorities and international bodies. Addresses of establishments and names of leading officials.

3 Technical Data
Articles and tables on reactor physics, instrumentation and special metallurgy.

4 Isotope Section
A 60-page table giving the principal properties of all known nuclides including indication of sources of supply. Precautions to be taken in the use of radioactive substances.

5 Company Addresses
Titles, addresses, directors, home and overseas branches of nearly 2000 British firms supplying the nuclear energy industry.

6 Buyers' Guide
Firm's products classified under 750 different headings.

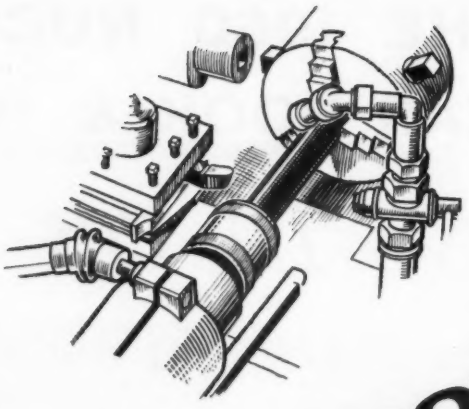
7 Trade Names
Products identified under registered titles.

8 Who's Who
Biographical details of over 600 leading men in British nuclear energy.

Revised from cover to cover the 3rd edition of NUCLEAR POWER YEAR BOOK and BUYERS' GUIDE is essential for management, designers, operators and research workers in the field of atomic energy.

Order your copy now—price £2.12.6 (post free)

ROWSE MUIR PUBLICATIONS LIMITED,
THE ROWSE MUIR BUILDING, 77-79 CHARLOTTE STREET, LONDON, W.1, ENGLAND



REMOTE CONTROL

The remote handling and machining of radio-active materials calls for design and construction of equipment by engineers who have a sound background in special-purpose machinery and machine tool production. More important, they must have a detailed knowledge and appreciation of the problems peculiar to the Nuclear Industry.

J. EVANS & SON (Portsmouth) LTD

We have both the engineering skill and "know-how." With the close collaboration of the United Kingdom Atomic Energy Authority, we have already designed and installed equipment at the Dounreay, Windscale and Springfields plants.

The illustrations show the exterior and interior installation of a remotely controlled precision lathe for the machining of irradiated fuel elements at Dounreay.

We shall be pleased to visit you at any time and you are cordially invited to our works where selected films and a most interesting range of activities can be seen.

MARCYN WORKS,
GOLDSMITH AVENUE, PORTSMOUTH
Telephone: PORTSMOUTH 32233

A Vital contribution to Atomic Power . . .

"WANDLESIDE"

ARMOURED CABLE

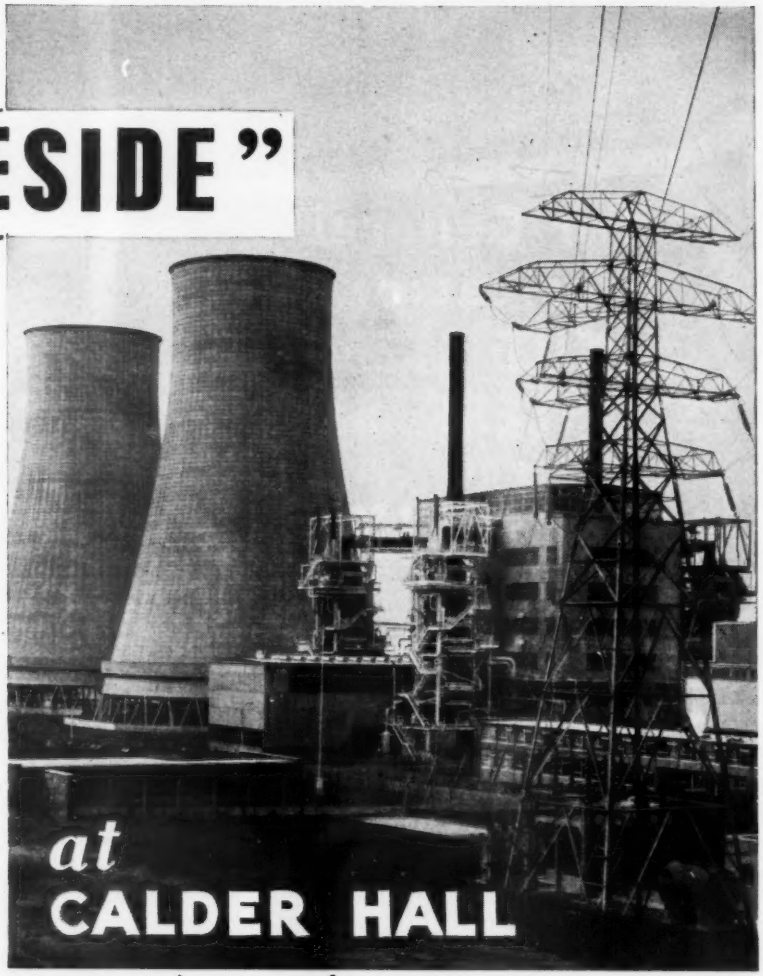


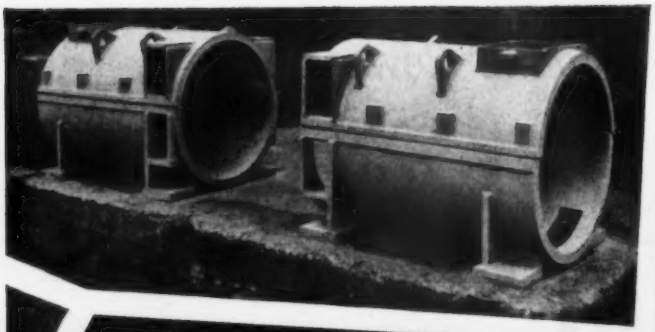
Photo by courtesy U.K. Atomic Energy Authority

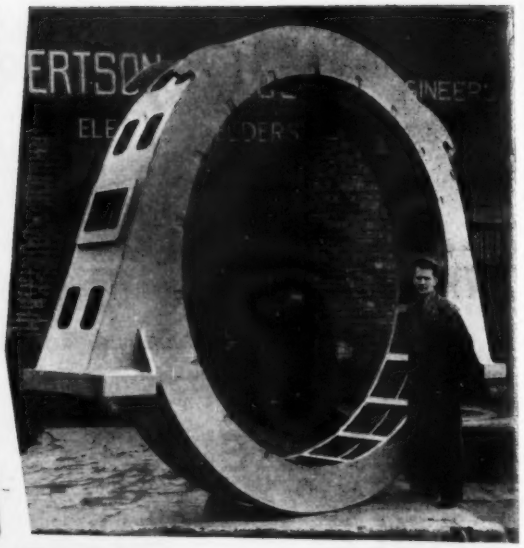
With the advancement of Atomic Power, cables must play an important part in the efficiency and reliability in the production of Nuclear Energy. Only the best is good enough and Wandleside Cables are eminently suitable.

WANDLESIDE CABLES *for Nuclear Energy*

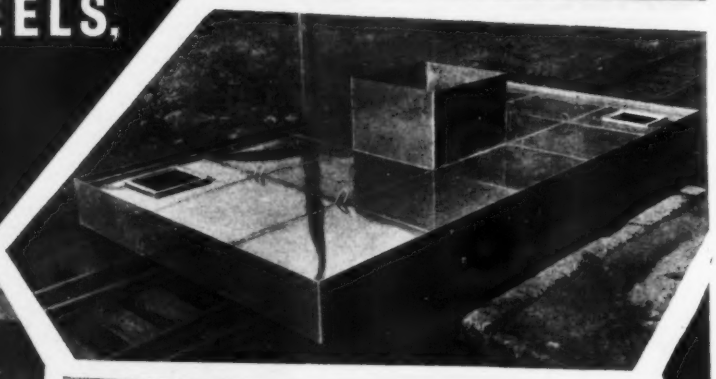
WANDLESIDE CABLE WORKS LTD. 106 GARRATT LANE WANDSWORTH LONDON, S.W.18
One of FALKS Group *Telephone: VANdyke 7544 (5 lines)* *Telegrams: Wandleside, London*

Circle **No 47** on reply card for further details



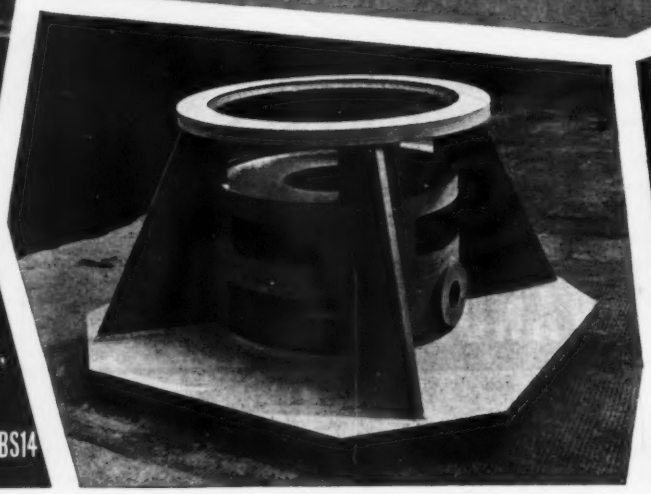


For General Fabrication in MILD STEELS, STAINLESS STEELS, and ALUMINIUM ALLOYS



ROBERTSON & FERGUSON LTD.

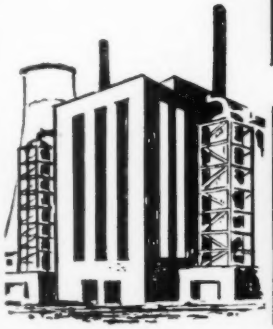
29 MURIESTON CRESCENT, EDINBURGH, 11. Tel: DON 5222



WE ALSO SPECIALISE IN DISHED AND FLANGED ENDS
MAX. DIA. 24" MAX. THICKNESS ½"
Made to suit Customer's inspection requirements from BS14

GRAPHITE MACHINING

Powell Duffryn Carbon Products Ltd.
are the official contractors
to the General Electric Company
for the machining of Nuclear Graphite.



THE POWELL DUFFRYN GROUP OF COMPANIES

POWELL DUFFRYN CARBON PRODUCTS LTD.,
NUCLEAR GRAPHITE DIVISION
Springfield Road, Hayes, Middlesex. Telephone Hayes 3994

Circle **No 49** on reply card for further details

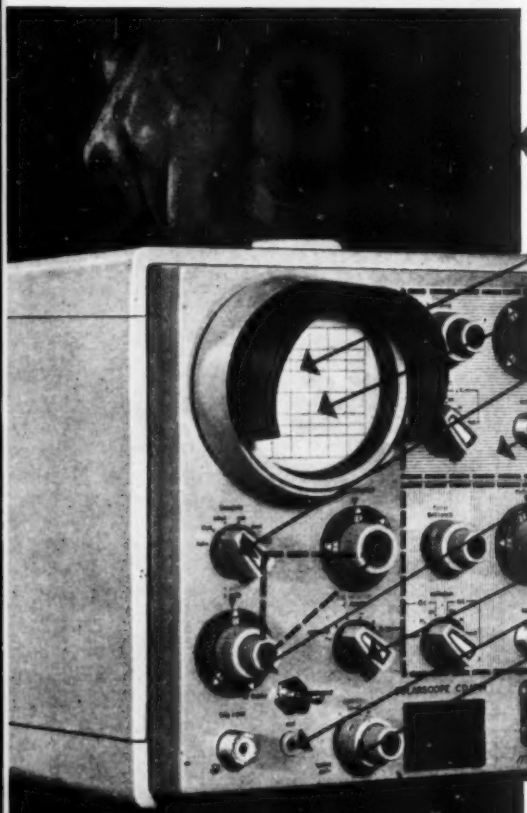
SOLARTRON

CD 1014 DOUBLE BEAM
OSCILLOSCOPE

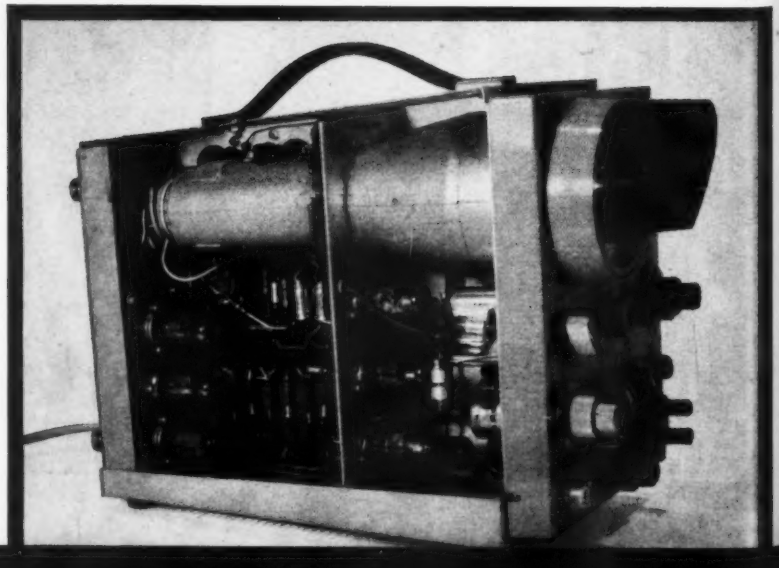
Circle **No 50** on reply card for further details

it has

and it's portable

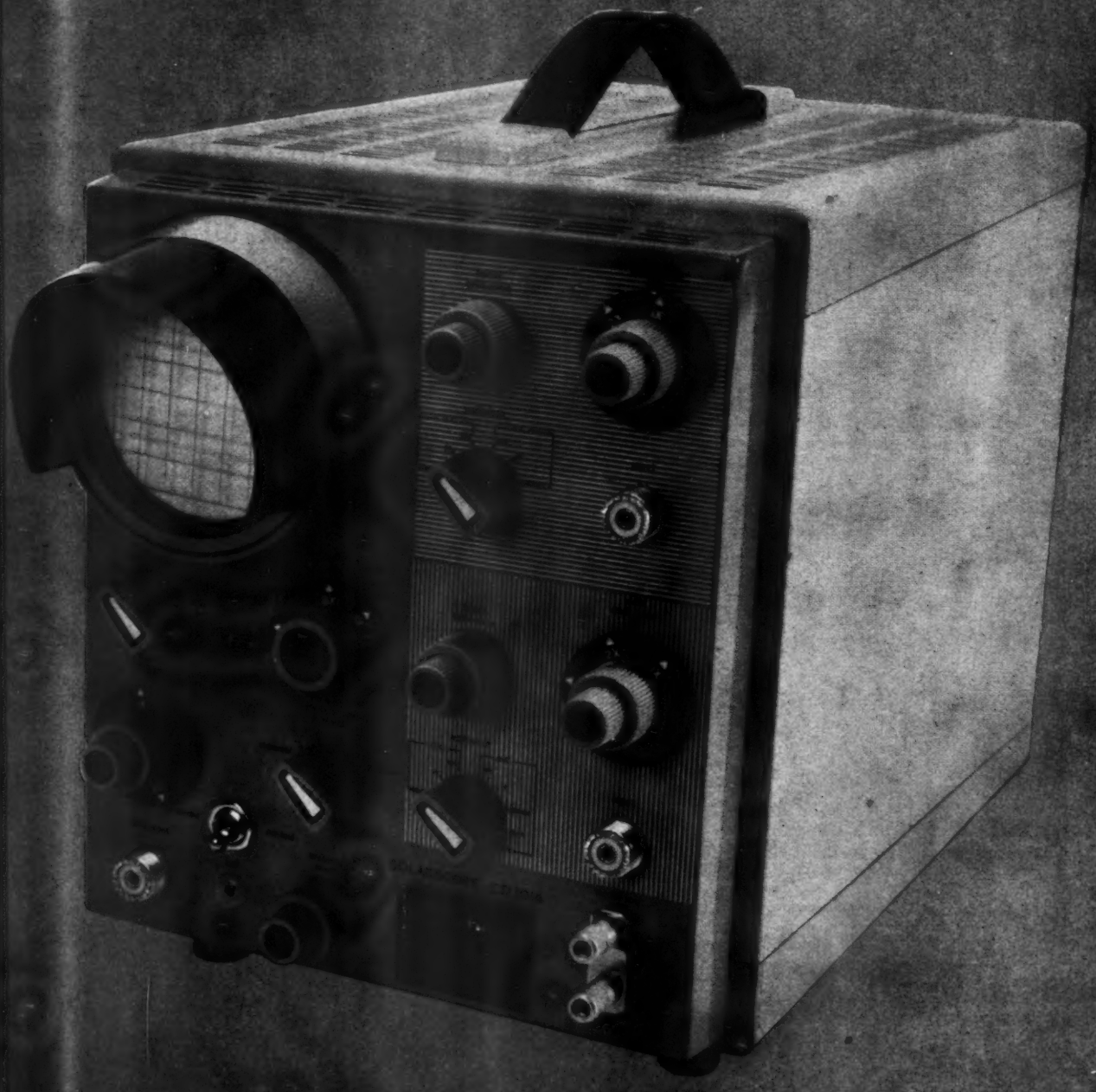


- Light and portable, weighs only 22 lbs, (10 kg.)
- Electronic Tubes 3AZP1 crt gives bright trace with excellent resolution. P7 phosphor crt also available.
- EHT 1.4 KV stabilised.
- Wide range time base 1μsec/cm — 1 sec/cm continuously variable.
- Velocity and amplitude calibration accurate to 5%.
- Y_1 and Y_2 DC-5 Mc/s (3db) at 100 V/cm — 100mV/cm
- Continuously variable times 10 X expansion & times 10 shift. continuously variable.
- Y_2 has additional integral pre amplifier giving 1mV/cm.
- TV frame sync. separator.
- 1% calibration waveform available.
- Trigger 'stability' and 'level' controls permit triggering from any selected point on a trigger waveform.
- Inputs can be 'floated' with respect to earth.
- New styling functional grouping of controls, ease of handling.
- Waveform available via cathode follower.
- Circuit economy throughout, only two valve types used, consumption 75 VA. Highest quality components used throughout.



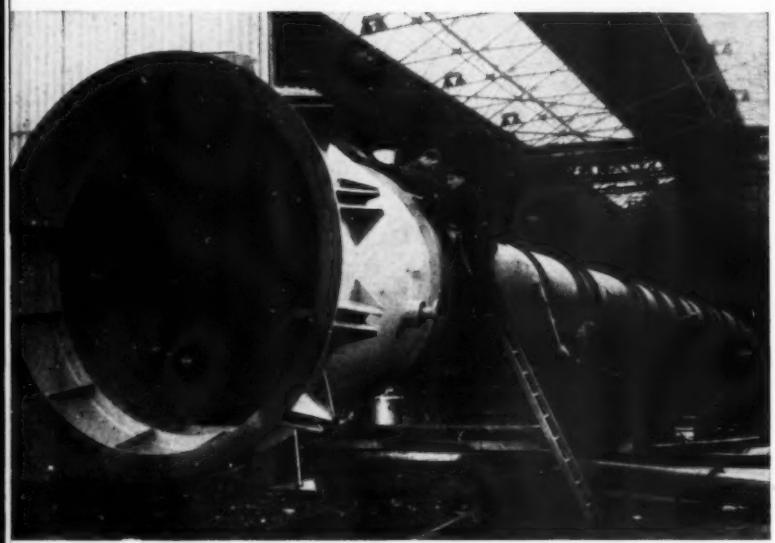
WRITE NOW
for full details

EVERYTHING !



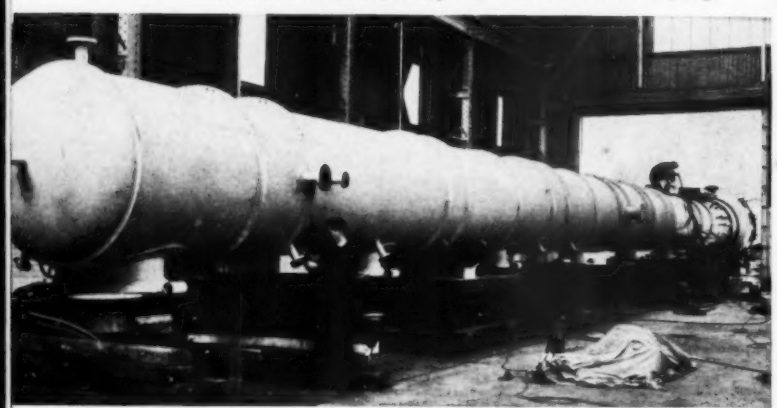
THE SOLARTRON ELECTRONIC GROUP LTD., THAMES DITTON, SURREY
Telephone: EMBerbrook 5522

Fabricated by NEWTON CHAMBERS



Our shops have been extended to deal with the largest vessels which can be transported, and include full facilities for automatic welding to Class I standards, X-Ray examination and stress-relieving.

This ETHYLENE TOWER, 118 feet long, was automatically welded, X-Rayed, and fully stress-relieved at our Works



This tower was supplied to MESSRS. STONE AND WEBSTER ENGINEERING LTD., *for the Grangemouth plant of* BRITISH HYDROCARBON CHEMICALS LTD.

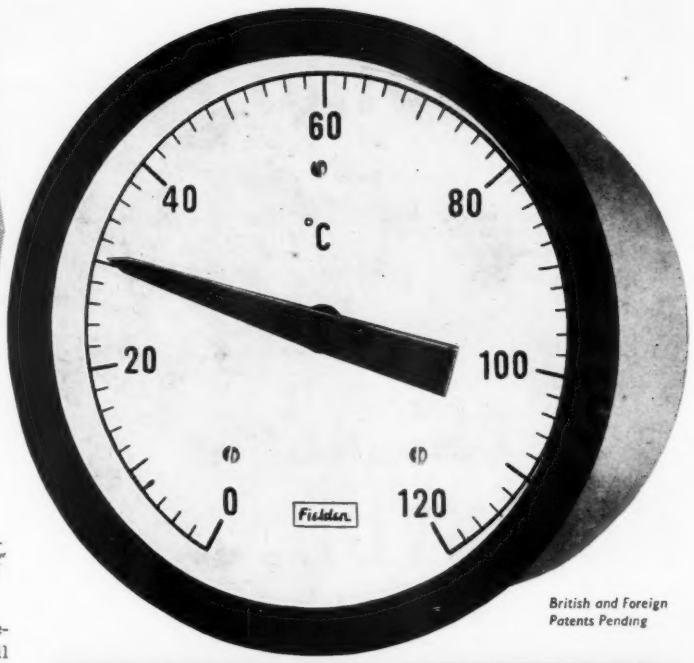
Newton Chambers

ENGINEERING DIVISION

ENGINEERS OF PROGRESS

NEWTON CHAMBERS & CO. LTD., THORNCLIFFE, SHEFFIELD

NEW



British and Foreign Patents Pending

VERY ROBUST. Sealed 6" diameter instrument, with measuring bulb in ¼" diameter stainless steel sheath.

LOW COST. A practical and economic replacement for filled systems and moving coil instruments — send for price list.

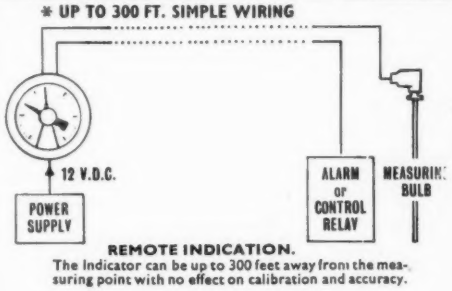
TRANSISTORISED. Exceptional reliability with a printed circuit and robust motor driven indicating pointer. 12 volt battery or mains supply.

EASILY FITTED. Simple clamp mounting with robust terminals. No fragile capillary tubes or expensive compensating cable — simple wiring only required.

ACCURATE AND RAPID RESPONSE. Reproductibility better than 0·25% on 13" scale, response time 1 second.

73 TEMPERATURE RANGES in °F and °C for temperatures up to 850°C.

'BIKINI' TEMPERATURE INDICATOR



REMOTE INDICATION.
The Indicator can be up to 300 feet away from the measuring point with no effect on calibration and accuracy.

ALSO . . .

"BIKINI" CONTROLLER
Differential 0·5°C. Includes similar features to the Bikini Indicator. Send for specification sheet BIK. 1 and price list.

"BIKINI" INDICATOR/CONTROLLER
The Indicator can be supplied with an adjustable control contact for use with local or remote alarm or control relay.

Send for Specification Sheet BIK 2/NP and Price List.

Fielden

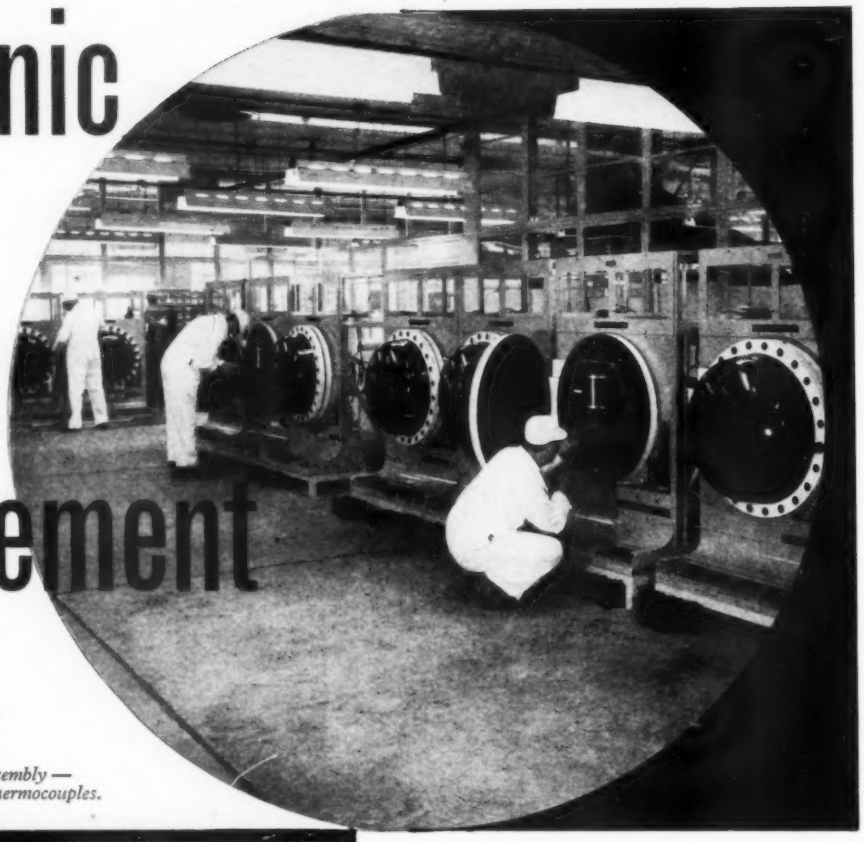
FIELDEN ELECTRONICS LTD · WYTHENSHAWE · MANCHESTER Phone: Wythenshawe 3251 (4 lines) Grams: Humidity Manchester
ALSO AUSTRALIA, ITALY AND CANADA *Branch Offices:* LONDON, WALSALL, STOCKTON-ON-TEES, EDINBURGH (A. R. BOLTON LTD) AND DUBLIN.
Agents throughout the world

Indicating Recording Control

B3

Circle **No 53** on reply card for further details

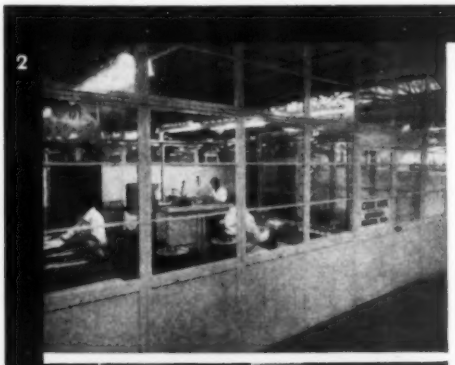
Nucleonic Achievement



1 *Precipitators for Hinkley Point nearing completion in the clean area major assembly shop.*

2 *Assembly of ion chambers; a self-contained unit in the clean area.*

3 *Another example of clean area assembly — the welding of high-temperature thermocouples.*



Plessey Nucleonics Limited is engaged, exclusively, in the design and manufacture of nuclear equipment and instrumentation; this includes BSD and flux scanning systems for reactors, radiation detectors of all types, both portable and installed, and instruments for process control, health and defence.

The parallel production of so much that is complementary in nuclear instrumentation has established within the Company an accumulation of scientific skills and experience which is quite unique in the world of nucleonics. These specialised techniques and knowledge are now offered for the development of new projects, and Plessey technical liaison engineers are freely available to discuss problems and propositions concerning nuclear instrumentation.

Plessey nuclear instrumentation has gained WORLD-WIDE ACCEPTANCE. The Company's BSD equipment has, for example, been chosen for every one of the following reactors:

RESEARCH REACTORS		POWER REACTORS	
WURENLINGEN	SWITZERLAND	CALDER A	CUMBERLAND
KARLSRUHE	W. GERMANY	CALDER B	CUMBERLAND
D.I.D.O.	HARWELL	CHAPELCROSS A	DUMFRIESSHIRE
P.L.U.T.O.	HARWELL	CHAPELCROSS B	DUMFRIESSHIRE
D.M.T.R.	DOUNREAY	BRADWELL	ESSEX
W.T.R.	U.S.A.	MARCOULE	FRANCE
A.G.R.	WINDSCALE	HINKLEY POINT	SOMERSET
		LATINA	ITALY
		TRAWSFYNYDD	N. WALES

Plessey

PLESSEY NUCLEONICS LIMITED

Weedon Rd · Northampton · Tel: Northampton 4966

Overseas Selling Organisation:

PLESSEY INTERNATIONAL LIMITED · Ilford · Essex · Tel: Ilford 3040

PNL/B

the SERCK organization

is actively concerned in the supply of equipment and material with special application to the Nuclear Power Industry

PRIMARY AND SECONDARY SURFACE

HEAT EXCHANGERS, CONDENSERS,

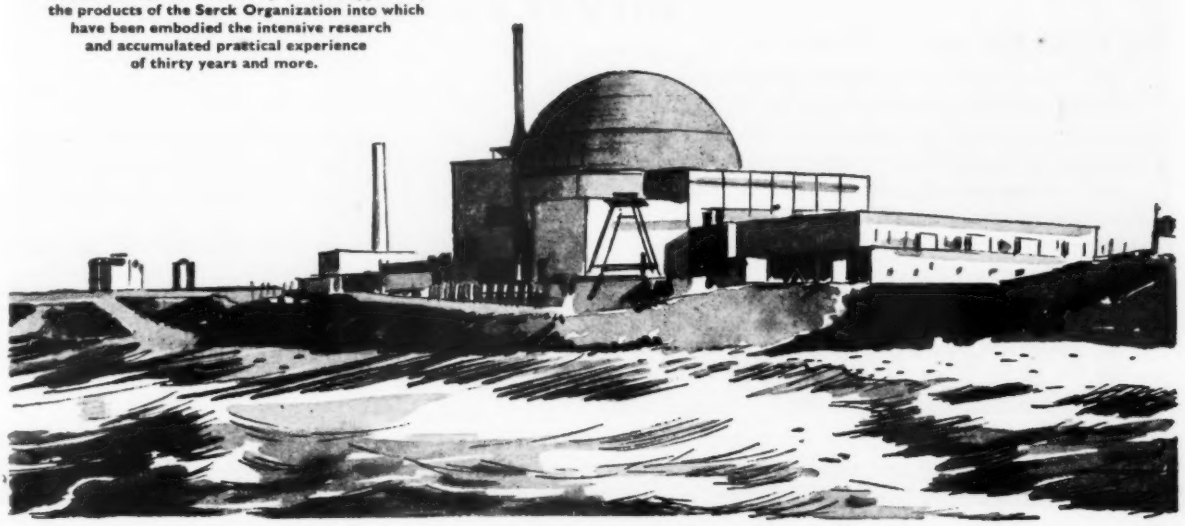
AIR AND GAS COOLERS,

SERCK RADIATORS LIMITED

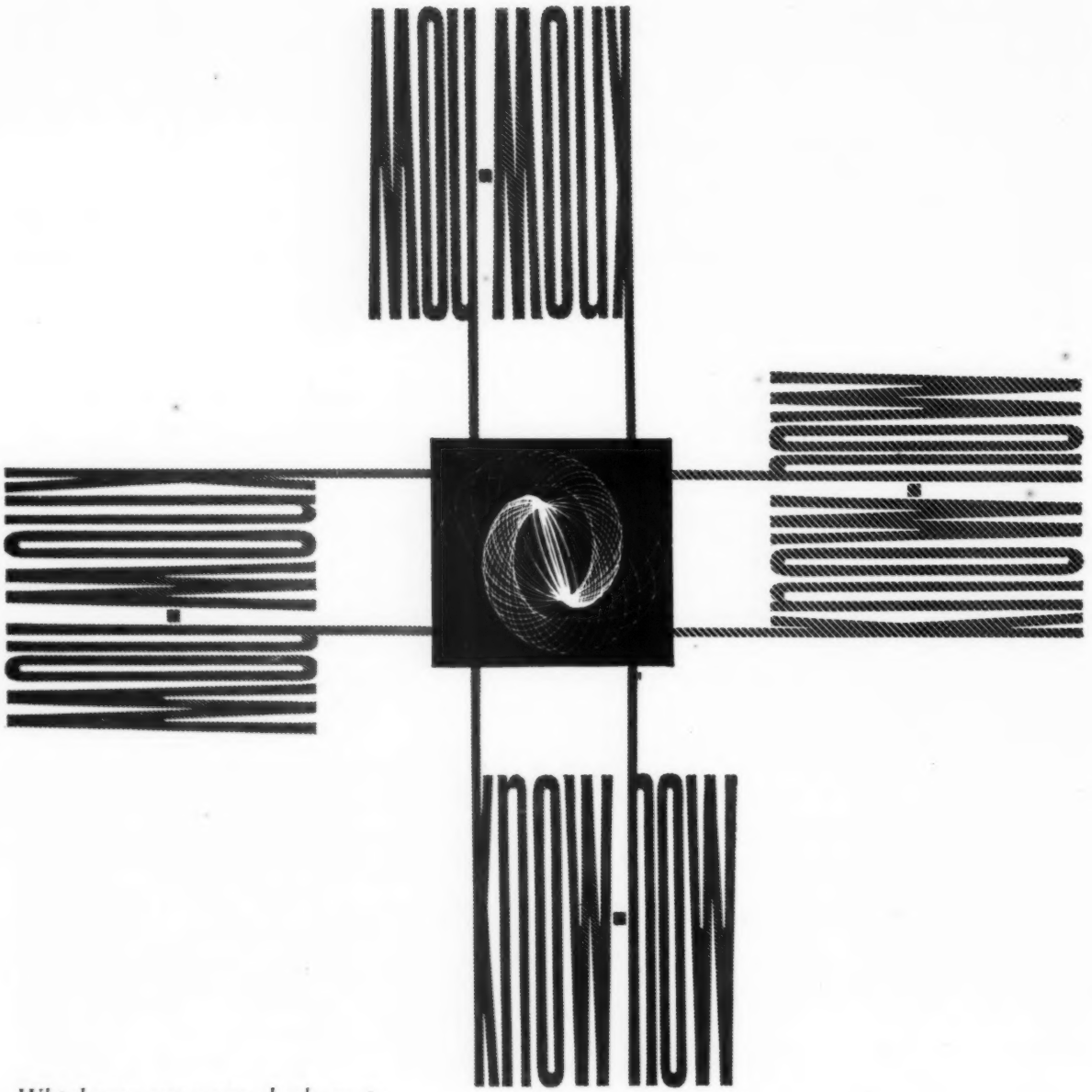
WARWICK ROAD, BIRMINGHAM 11

A member of the SERCK GROUP

A first class Technical Advisory Service supports the products of the Serck Organization into which have been embodied the intensive research and accumulated practical experience of thirty years and more.



Circle **No 55** on reply card for further details



Whichever way you look at it . . .

know-how is of primary importance in the manufacturing of Atomic Energy Equipment. This is where Graviner scores, for we can make almost anything in this rather new sphere of activity, whether it be a lead-filled shielded container, a Thulium storage magazine, a magnet for neutron beam focusing or a 20 ton mobile cell unit with viewing windows and handling equipment. We specialise too, in the machining of graphite. Indeed, with the recent addition of 12,500 square feet of factory space we can deal with anything from the making of a tiny graphite spring to a Reflector for a Reactor — all under controlled clean conditions.

If therefore you have a Development or Production problem, our Nuclear Energy Division will be very pleased to help you. Won't you pay a visit to the Gosport Factory and see what we can do ?

GRAVINER *Contractors to The Atomic Energy Authority*

FAREHAM ROAD · GOSPORT · HAMPSHIRE · Telephone Fareham 2511

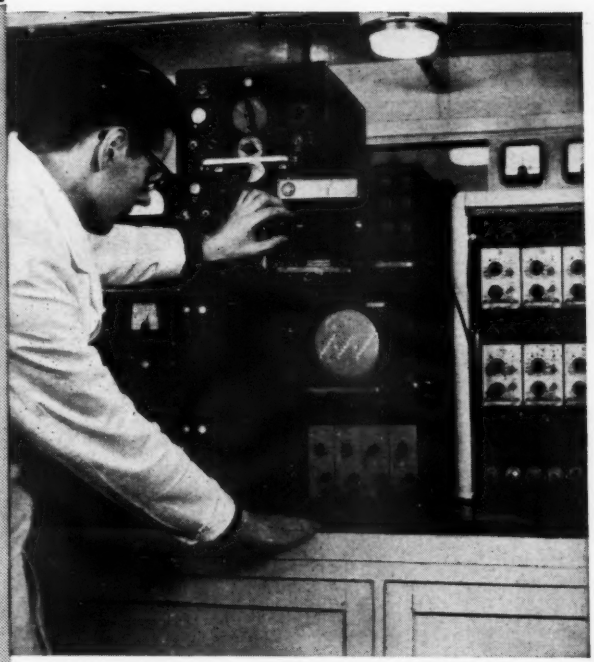
Also specialists in Airborne, Diesel Engine and Industrial Fire and Explosion Protection, Thermostats and Overheat Switches

Data Handling Systems

DIGITAL

The DIDAS Transmitter

891362	108572
243895	925841
239810	189463
654958	194857
193847	237583
901205	867493
294736	910485
271057	839120
984752	856321
379824	658493
105447	539582
459233	937562
811278	423038
532485	902475
114857	521054
984735	284731
927411	883746
210473	937561
567482	109235
665820	991375
857395	274837
948573	198573
195847	958473
248571	984421
125434	103425
354321	978679
748275	213486
859483	210084
942106	330198
772689	921006



DIDAS receiving and recording in laboratory conditions

- Fully Transistorized
- Extremely High Speed
- Compact
- Reliable
- Modern Construction
- Rugged but light

Speedy measurement and analysis of data has become a necessity in modern industry. Armstrong Whitworth Aircraft have developed data handling systems for measurement and remote control. The data can be transmitted at the speed of light by radio, or by cable link, with extreme accuracy. In one system (the DIDAS vehicle system), over 250,000 different readings can be obtained in one minute. Analogue/digital and digital analogue convertors, working at over 50,000 conversions a second, eliminate processing bottlenecks. Systems can be engineered to customers' requirements.

DIDAS used on "Bluebird" Land Speed Record Run, U.S.A., 1960

SIR W. G. ARMSTRONG WHITWORTH AIRCRAFT LIMITED, Baginton, Coventry, England
(A member of Hawker Siddeley Aviation)

Maximum power, precision and production potential

Turbine machining carried out on INNOCENTI - CWB FAF 305/200 Milling and Boring machine. Complete machining, including boring, grooving, milling of joint face, and drilling carried out at one setting without use of boring bar.

are characteristics of INNOCENTI-CWB Milling and Boring Machines

Additional important features: Maximum versatility · Economical production · Jig boring facilities · Large diameter surfacing and boring at right angles to main spindle D.C. variable speed motors · Sliding headstock · Virtual elimination of boring bars Facilities for automatic remote control electric measuring · All-electric—no electronics Minimum maintenance · Remote pendant control.

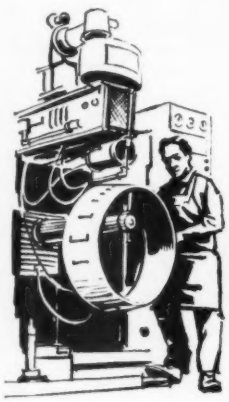
Inserted by Henderson & Keay Ltd., Agents in Great Britain for INNOCENTI Mechanical Division, Milan

HENDERSON & KEAY LTD. : 189 PITT STREET : GLASGOW C.2

Telephone : CENTRAL 0261

A true word spoken in jesture!

Without successful WELDING there can be no successful Nuclear Engineering. So why gamble? Call in the welding SPECIALISTS — Vandyke of Harlow. Recent contracts include welded fabrications for Winfrith Heath and Harwell. Full inspection facilities are available of course, including vacuum testing and radiography.



For Victory over welding problems, remember VANDYKE

VANDYKE ENGINEERING LTD

for delivery, value and versatility

PINNACLES HARLOW ESSEX HARLOW (Essex) 24652 (P.A.B.X.)

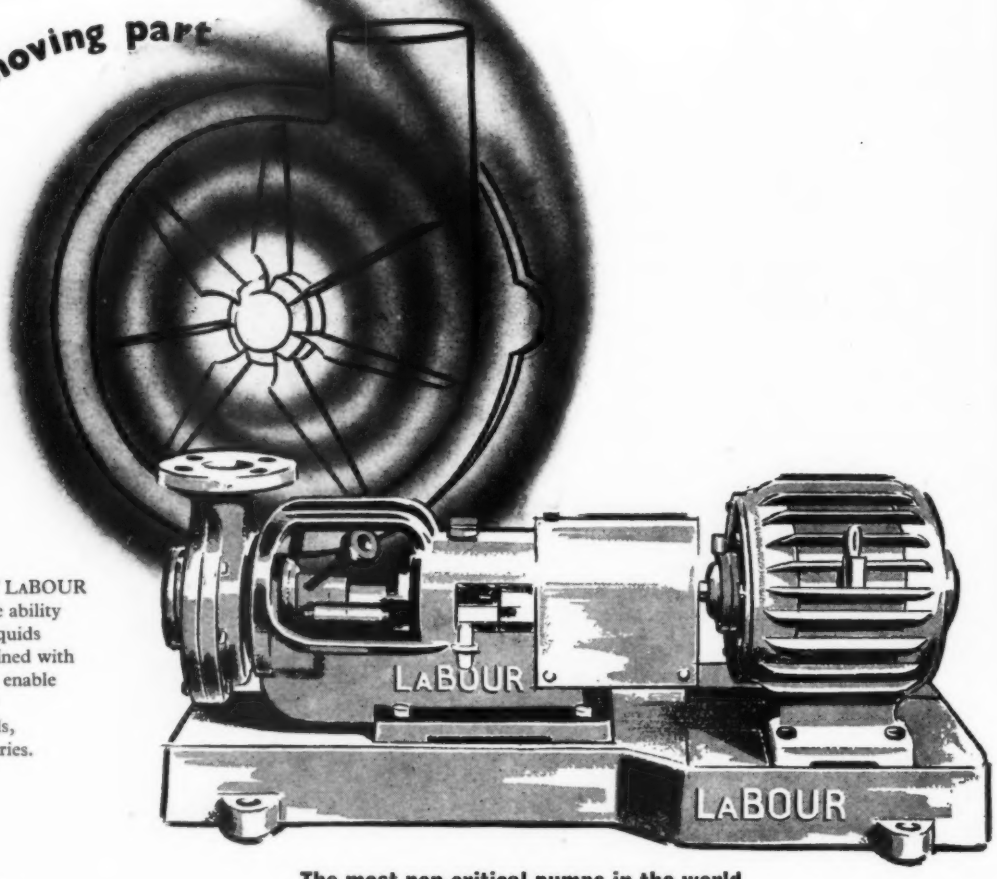
LABOUR

3-way winners

open type impeller

generous clearances

only one moving part



These features of LABOUR pumps ensure the ability to handle dirty liquids and liquids entrained with gases or vapours; enable pumps to handle all types of liquids, effluents and slurries.

The most non-critical pumps in the world

NO CORROSION

LABOUR

originators of the first practical self-priming pump

BRITISH LABOUR PUMP CO LTD

Blundell St London N7 Telephone: North 6601-5 Grams: Laboupump London

P4319

RIO TINTO

Rio Tinto, producers of uranium and thorium, will play an important part in the future industrial use of nuclear power through the following companies:

Rio Algom Mines Limited, CANADA
will amalgamate the four Canadian uranium mining companies under Rio Tinto's management to form the largest uranium producing company in the world.

Thorium Limited, UNITED KINGDOM
owned by Rio Tinto and Dow Chemie A.G., processes crude thorium materials and markets a variety of refined thorium and rare earth compounds.

Mary Kathleen Uranium Ltd, AUSTRALIA
managed by Rio Tinto in Australia, is now in full production and supplying uranium oxide for Britain's nuclear power stations.

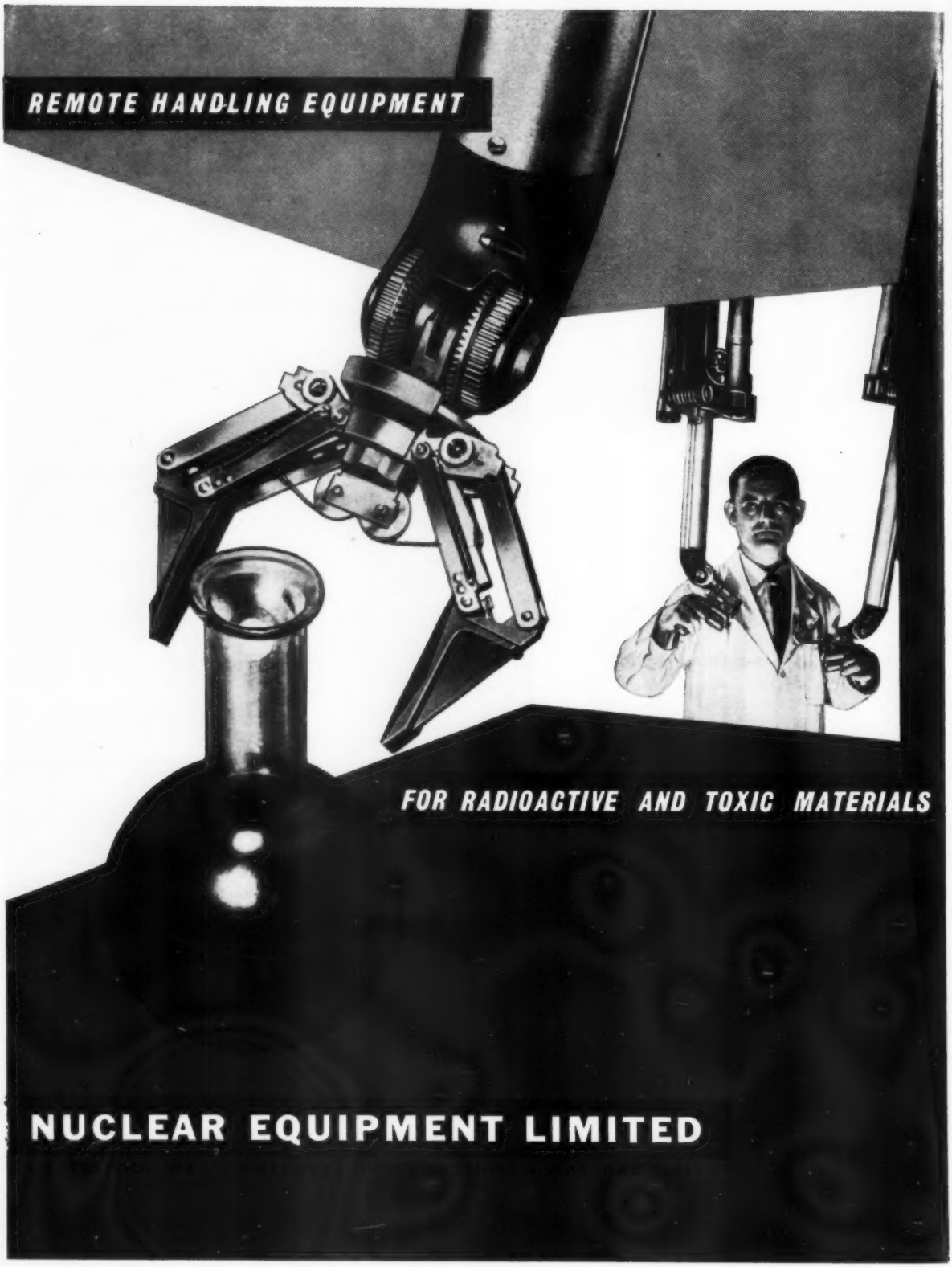
Nukem-Nuklear-Chemie und-Metallurgie G.m.b.H., GERMANY
has been formed by Deutsche Gold-und Silber-Scheideanstalt (Degussa), Rio Tinto and Mallinckrodt Chemical Works to manufacture nuclear fuel materials and fuel elements.

Rio Tinto Dow Limited, CANADA
Rio Tinto and the Dow Chemical Company of Canada are collaborating in uranium processing and producing thorium as a by-product of uranium.

Austro-Chematom Kernbrennstoff G.m.b.H., AUSTRIA
formed by Osterreichische Stickstoffwerke A.G. in association with Rio Tinto and Degussa to manufacture nuclear fuel materials and fuel elements.

Rio Tinto Management Services (U.K.) Limited
BARRINGTON HOUSE, 59 GRESHAM STREET, LONDON, E.C.2

Circle **No 61** on reply card for further details


REMOTE HANDLING EQUIPMENT
FOR RADIOACTIVE AND TOXIC MATERIALS
NUCLEAR EQUIPMENT LIMITED

Nuclear Power
REACTORS MATERIALS INSTRUMENTATION PROCESSES IRRADIATION

OCTOBER 1960 VOLUME 5 NUMBER 54

VIEWPOINTS *letters to the Editor*

Power station costs

SIR: In your September issue Gracchus remarks that the price of £98/kW quoted by other journals for Dungeness has been proved incorrect by Sir Christopher Hinton's figure of £110/kW in his Royal Society lecture.

There is nothing mysterious about the discrepancy if one is careful to distinguish between the price to the contractor and the total station cost.

When Sir Christopher Hinton quotes the cost of a power station he must add to the main contract price his own costs for purchase of land, improvement of site approaches, a contingency for extras and his own engineering charges. In general, on nuclear stations this cost amounts to £10 or £12/kW.

I think you will agree too much loose talk can arise from the misinterpretation of terms, deliberate or otherwise. There was a time when some manufacturers referred to the nett electrical output of a station whilst others referred to the gross electrical output. Amid such confusion it was virtually impossible to make fair comparisons of the price per kW. Can, I therefore, make a plea for a clear distinction between contract price and total station costs whenever you are quoting the price per kW.

The Nuclear Power Group, Radbroke Hall, Knutsford R. D. VAUGHAN CHIEF ENGINEER

GRACCHUS *writes: I accept the points made by Mr Vaughan but my implied criticism of other published figures was that, in fact, they made no distinction between the contract price and the total station cost. Perhaps these matters could be cleared up if the contract price were revealed at the time the contract is granted.*

Steam cycles

SIR: In his article on Steam Cycles for Power Reactors in the September issue, Mr W. J. Thomas implies that the Tokai-Mura power station under construction in Japan uses a non-reheat double-pressure cycle in common with the 'first round' British stations. In fact, as described in NUCLEAR POWER for March 1960, the Tokai-Mura station has its gas circulators driven by back-pressure turbines which consume almost all of the high pressure steam generated and exhaust it to the low pressure system where it is reheated in the steam-raising units before passing to the main turbines. According to recently published information, Dungeness will use a similar steam cycle.

In spite of the use of reheat the overall sent out efficiency at Tokai-Mura is only expected to be 27·7%. This is lower than for the British stations because of the higher temperature of the available circulating water (20°C compared with 13°C for most British stations), and also because in order to achieve a low generation cost, a possible increase in efficiency was sacrificed in the design in order to obtain a highly rated and, therefore, low cost reactor. With natural uranium reactors the contribution of fuel consumption cost to total generation cost is so much smaller than that of capital cost that efficiency on its own may be a misleading criterion for the comparison of nuclear power stations and plant costs must also be taken into account.

GEC & Simon-Carves Atomic Energy Group R. H. BIRD CHIEF PERFORMANCE ENGINEER

MR THOMAS *writes: Mention is made in Part II of the article which appears in this issue that Tokai-Mura uses reheat in its steam cycle. The reasons given for the level of overall sent out efficiency being established at 27·7% are of interest. These are in accord with the third paragraph of the first article under the heading 'Steam Cycle Economics', where it is made clear that the optimum total generating cost is not defined by lowest capital cost or highest thermal performance but a balance between both.*

SIR: Would you be kind enough to point out to your readers that fig. 7 on page 111 in the article by W. J. Thomas in your September issue is taken, with slight modifications, from my recent paper on 'Wetness in Steam Cycles' given before the Institution of Mechanical Engineers.

There are also minor errors which do not appear in the original. For instance, the figure on the right of the entropy axis should be 1·9, not 1·0 and the correct symbol for entropy, according to BS 1991, is S, not Q.

Merz & McLellan, Esher, Surrey B. WOOD

Siting nuclear stations

SIR: At present the electrical industry is trying to solve the problems of its own expansion *in vacuo* by selecting sites which are as nearly perfect for the purpose of generating electricity as the diverse terrain of these islands will allow, without considering other contingencies and other and probably better claims on the land. So far the CEGB have had their way and are in the process of erecting nuclear stations in such unlikely places as the Snowdonia National Park and the Dungeness Nature Reserve, as well as four other remote, beautiful and hitherto unspoiled country sites.

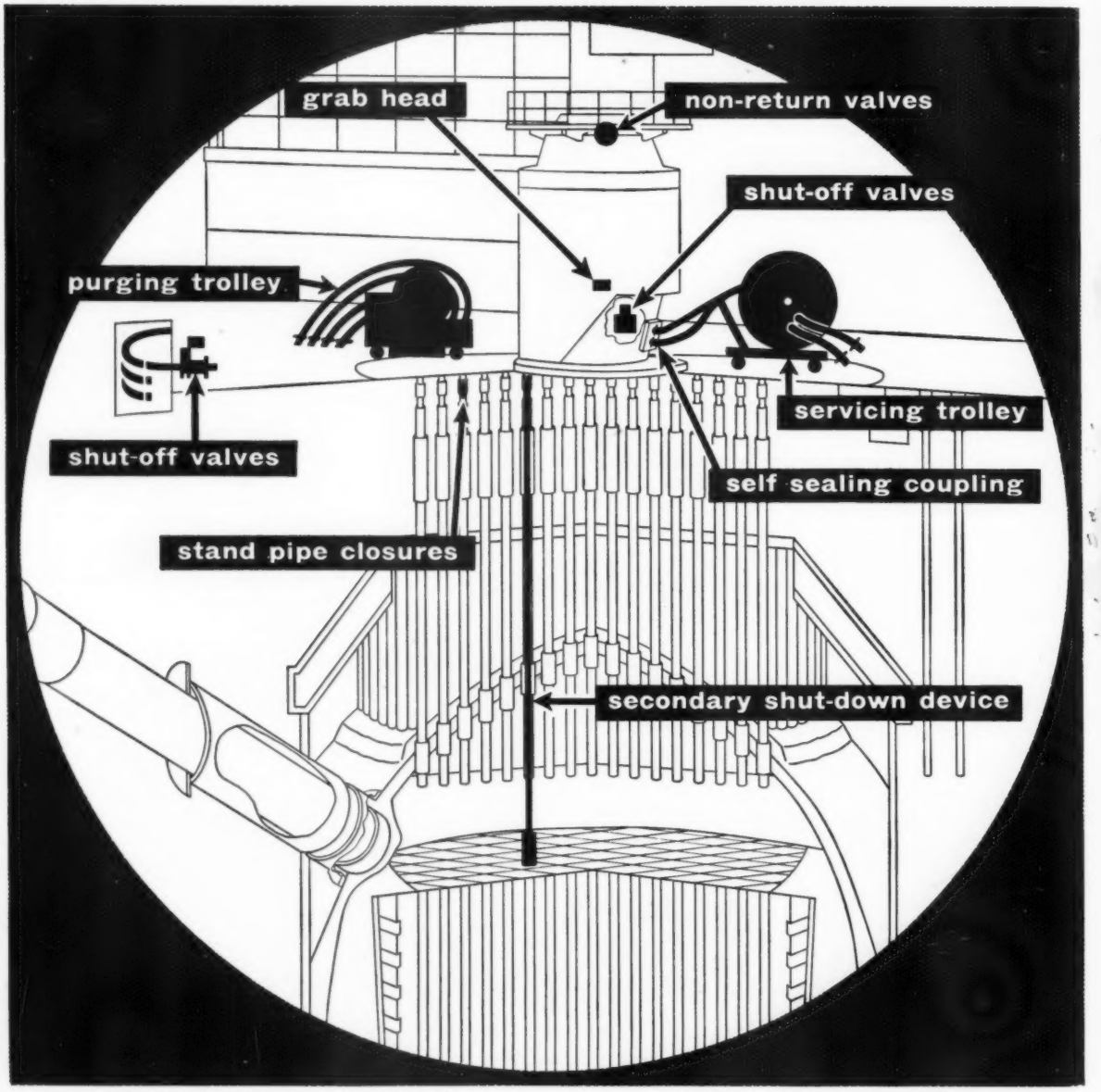
There are, on the other hand, cogent reasons for assembling power stations as close as possible to centres of industry and population. Among these is the urgent need to make use of their waste heat. The Trawsfynydd station, in dissipating its waste heat, will raise permanently the 7300 million gallons at Trawsfynydd Lake an average of 10°F. This will be a prodigious and reckless waste of energy.

Sir William Cook of the Atomic Energy Authority said recently that the use of advanced gas cooled reactors will allow a relaxation of siting restrictions so that nuclear power stations can be placed in built-up areas. He also said he expected advanced gas cooled reactors to be ready in time for use on some sites already selected for nuclear stations.

It will be a thousand pities, should Sir William's predictions come to pass, if the remote sites already selected are not relinquished in favour of sites near existing centres of industry and population. To place, for example, a 500 MW AGR at Wylfa Head in Anglesey would not only be a needless act of despoliation but also one of commercial shortsightedness.

GERALD HAYTHORNTHWAITE
Chairman, North Wales (Hydro-Electricity) Protection Committee

FR services to the NUCLEAR INDUSTRY



Flight Refuelling Ltd

Tarrant Rushton Airfield, Blandford, Dorset. Telephone: Blandford 501

OPINION

University reactors

NOT A SINGLE reactor is yet operating at a United Kingdom university although the number available throughout the world is now quite large. Since the world's first university reactor went critical at the College of North Carolina in 1953, more than 40 other reactors for research and teaching have been installed in the United States.

The recent University Reactor Conference in the United States, the third of its kind since 1954, is reported by Mr Hughes on pages 99-101 of this issue; it comes at an opportune time, for its main theme 'Why a university reactor?' coincides with the US Atomic Energy Commission's decision not to finance any more teaching reactors and the National Science Foundation's omission of any allowance for new research reactors in its coming financial budget.

The general impression we gained from the conference was that, while a number of reactors may have been obtained for prestige value, some US university reactors are being put to good use and the output of research work was outstanding. Much of this is due to the enthusiasm of the staff, however, a factor that seems to be independent of the reactor power range. Commenting on the tendency of some people to associate more and more research with higher and higher flux, Professor Thompson of the Massachusetts Institute of Technology considered the real trend ought to be towards more and more research with lower and lower flux.

For teaching purposes, on the other hand, the usefulness of low power research reactors (below 10 kW) has met with criticism on quite a number of occasions. It has been argued in our correspondence columns that teaching needs are adequately met by simulators and other facilities. American universities with no separate department for nuclear energy say they are meeting all their teaching requirements with heat transfer rigs, a cobalt-60 source and a subcritical assembly. One of our correspondents has likened the present teaching reactor trend to the 'cyclotron mania' of the thirties when nearly all American universities rushed to buy equipment that soon became obsolete as a research tool and of very little use as an educational aid. In support of the low power teaching reactor, it is pointed out that only by actual operation can undergraduates and future reactor operators receive effective training—and a regular supply of trained research workers from universities is very important to the nuclear industry.

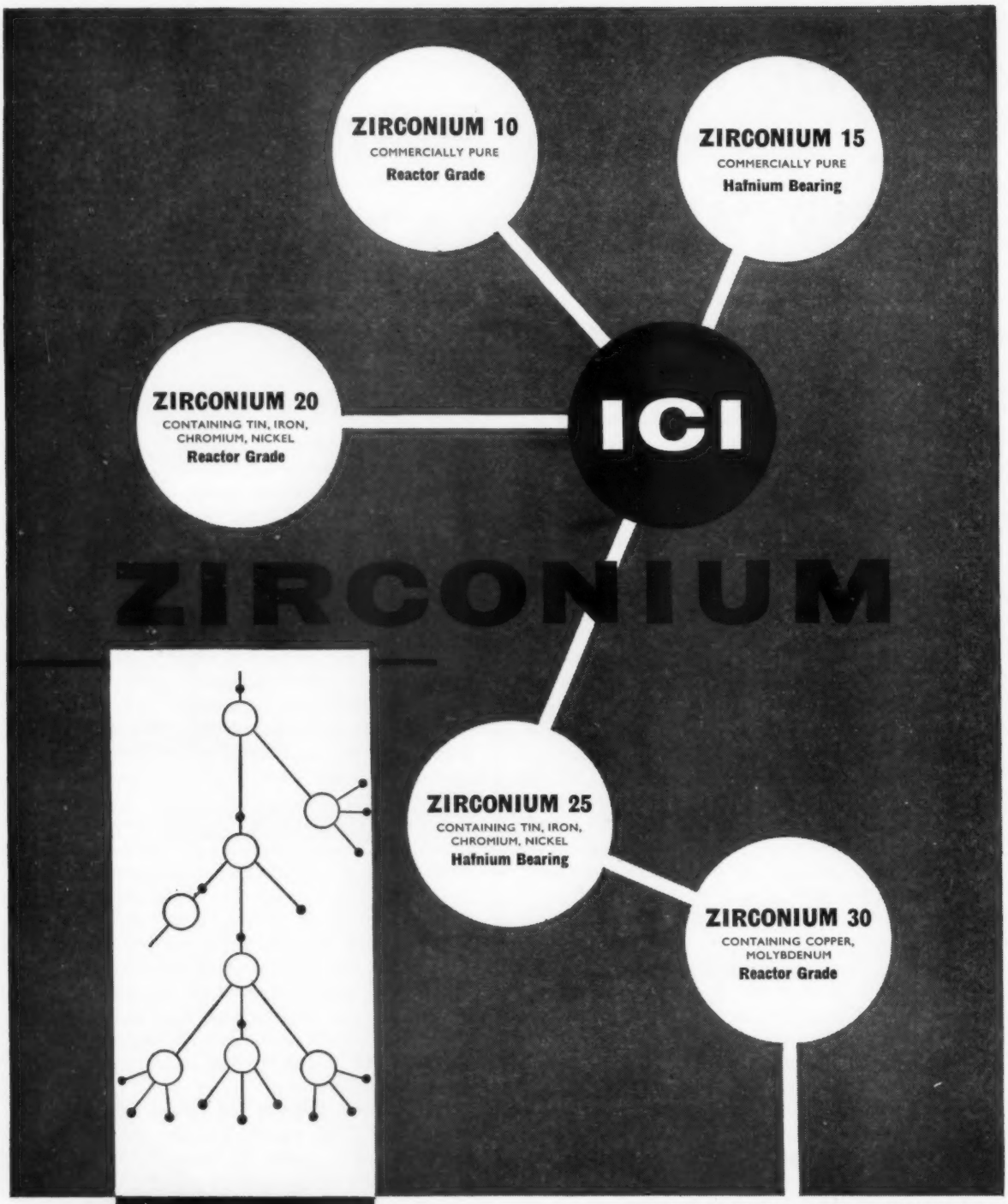
Excluding teaching functions, reactors enable many important areas of research to be explored in particular: activation analysis, danger coefficient analysis, macroscopic cross-section measurements, exponential experiments, flux distribution measurements and low-level irradiation studies. There are aspects of research that will not, or cannot, be undertaken by the UKAEA and the provision of a radiation facility in the university under a competent professor with a full long-term programme will do a lot of good for the industry and the country. At the same time, undergraduates in the same establishment can benefit if the reactor is made freely available.

A look at the successfully operated research reactors in the United States shows intensive programmes covering not only such exercises as approach to criticality, control rod calibration, reactor kinetics, experiments in radioactivation analysis and spectrum measurement, but also experiments in neutron therapy, the development of energy dependent scintillation counters and effect of irradiation on solid-state catalysts.

In view of the considerable theoretical background and the ancillary services that are required, the operation of a research reactor raises a number of questions apart from that of costs; is any UK university capable of operating one and providing adequate safety facilities? Should reactor experiments be carried out beyond the confines of the Authority? If these projects are to see the light of day, they will presumably be financed by Government grants and it is a public duty to exercise caution in this direction.

A possible solution may be the sharing of an existing facility; AEI, for instance, have made arrangements with certain universities for cooperative research on Merlin, and Hawker Siddeley are running courses with Jason.

The National Institute for Research in Nuclear Science, and DSIR, who have to face the problem of recommendation, cannot be expected to deliberate hastily in view of the opinions expressed at the US University Reactor Conference. Reactor proposals will have to be carefully scrutinized and related to the long term programme. Another reason for anticipating slow deliberation on university proposals is the problem raised by urban siting, one that has received the attention of the newly formed UK Nuclear Safety Committee. Early publication of its deliberations is urged so that the National Institute, the universities and the reactor industry can decide what direction to take.



WROUGHT FORMS AND FINISHED COMPONENTS

ICI
METALS
DIVISION

FIRST IN NUCLEAR METALS

IMPERIAL CHEMICAL INDUSTRIES LIMITED, LONDON SWI

NC.4

Circle **No 64** on reply card for further details

WORLDVIEW

the month in atomic energy

EUROPE

English Electric to get Sizewell contract

London The contract for the Central Electricity Generating Board's sixth nuclear power station, due to be announced in a few months time, is now expected to go to the English Electric, Babcock & Wilcox, Taylor Woodrow group.

Alone among the tendering groups, they have received a questionnaire from the CEGB asking for clarification of certain points. If the answers to these are satisfactory, a contract can be expected to follow. For the Trawsfynydd station, Atomic Power Constructions Ltd received a CEGB questionnaire and the contract award followed; a similar occurrence took place over Dungeness when The Nuclear Power Group was sent a questionnaire and received the contract.

The English Electric, Babcock & Wilcox, Taylor Woodrow group gained their first nuclear power station order from the CEGB in autumn 1957, to build the 500 MW station at Hinkley Point, Somerset and the group set up a limited company, English Electric, Babcock & Wilcox, Taylor Woodrow Atomic Power Construction Co. Ltd, for the sole purpose of handling this particular contract. The constituent companies will continue to collaborate on gas-cooled reactors of over 150 MW constructed in the UK.

Meanwhile, according to the CEGB's publication 'Power News', work on the 550 MW Sizewell station may start in the early months of next year. A 2000-strong labour force, the report says, will complete the station some time in 1966. After that, a staff of about 400 will be required to maintain it.

Further points from this report are that the station will use 42 million gallons of cooling water and that there is room for extension to the power station at a later date.

New Winfrith research reactor

London A new zero-energy oscillator research reactor for the AEA Establishment at Winfrith Heath is to be built by Fairey Engineering Ltd. Known as Hector, it will use the 'pile oscillator' technique to study the nuclear behaviour of fuels, moderators and structural materials. The contract for the control gear design has been awarded to H. M. Hobson Ltd, Wolverhampton.

The reactor core is an annulus of graphite and highly enriched uranium/aluminium alloy within which various assemblies of fuel and moderator may be constructed around a central tube. The sample under investigation will be cycled through this tube.

Scheduled to go critical in 1962, it is believed to be the first in the world in which oscillator measurements can be carried out over a wide range of experimental conditions. The fuel material in the assembly may be natural or enriched uranium-235, plutonium, thorium, uranium-233, ceramic fuels, and irradiated fuel elements from power stations. Since the assembly can be heated to 450°C, samples will be studied under conditions found throughout the life of many different designs of power reactors.

AB Atomenergi plans ahead

Stockholm A fast zero energy reactor, FR-0, is planned for 1962–63 by AB Atomenergi, whose budget requirements for 1961–62 are placed at about five million crowns (£350,000) more than the previous year.

AB Atomenergi also says its Van de Graff accelerator will be in full operation during the coming year; its R-2 reactor will be on three-shift working and its R2-0 reactor on a two-shift working.

Future activities will be concentrated on fuller development of heavy water moderated reactors. These include homogeneous and direct cycle types.

• **Yugoslavia** A third research reactor is to be built at the Josef Stefan Research Institute at Ljubljana.

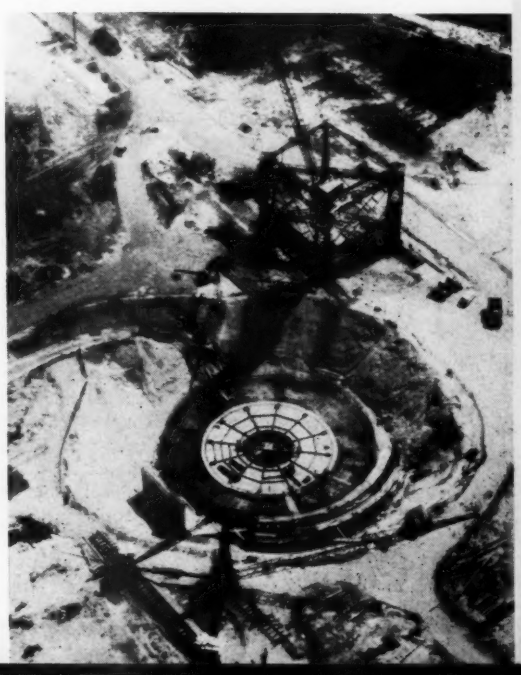
• **Italy** The National Committee for Nuclear Research and AGIP Nucleare have signed a contract on the design and building of an organic-moderated power reactor.

German power programme cut

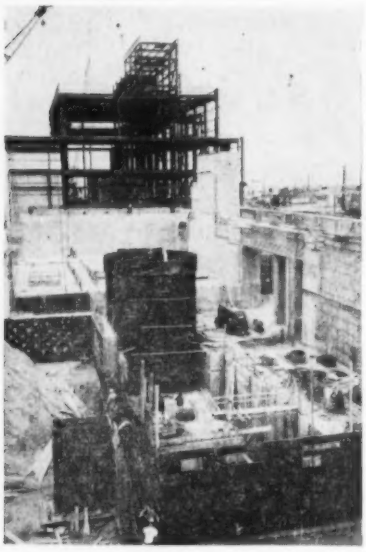
Bonn A cutback in the nuclear programme, similar to that in Britain (see *Worldview*, July, p 61), is to come into effect in Germany. This follows the announcement by the Ministry of Federal Assets that estimates for nuclear power development would have to be cut because of other, more pressing claims.

The programme has been financed so far from funds from the former European Recovery Programme. However, a large amount of this is to be devoted to aid for underdeveloped countries. In addition, some of the money allocated for nuclear power in 1959 and 1960 had not been used.

THE DRAGON SITE Work has already started on the building to house the OECC high temperature gas-cooled reactor at Winfrith Heath



WORLDVIEW



HALLAM The reactor core cavity liner is installed at the 75 MW sodium graphite reactor being built at Hallam, Nebraska

Isotope progress is reviewed

Copenhagen Progress made in radioisotope applications in the physical sciences and in industry was reviewed in detail at the International Atomic Energy Agency's International Conference on Radioisotopes held here. It was the largest scientific conference the IAEA has held so far and was attended by nearly 600 scientists from 42 countries.

The IAEA Director-General, Mr Sterling Cole, told the delegates that some papers presented had a direct bearing on the Agency's activities. For example, a great deal of development work had yet to be done in the application of isotopes to the study of schemes for hydrological development and in obtaining a better understanding of siltation and allied problems. In this field, the IAEA was initiating a large-scale programme with the aid of the World Meteorological Organization.

The Conference devoted one week to the use of isotopes in various branches of chemistry—from their use in analysis to determine extremely small amounts of material to their use in research for studying the mechanism of various chemical reactions.

Among the papers presented was one by Soviet scientists describing how a radioactive source could be used to find coal and possibly other ores. This source, placed in a bore hole, indicated the depth of the coal, thickness and structure of the seams.

Euratom discussion on protection

Brussels The first large public conference organized by Euratom, which lasted for three days, brought together experts from 15 countries to discuss legal and administrative problems of protection in the peaceful uses of atomic energy.

Held early in September, the conference covered four main fields: radiation protection, insurance, licensing of installations and international controls on radioactive contamination. It also dealt with the problems of enforcing the basic health protection standards which Euratom published in 1959.

Part of the conference, covering risks associated with nuclear shipping, was attended by a 12-man delegation from the British Parliamentary Labour Party led by Mr T. F. Peart, chairman of the Labour Party's Atomic Energy Sub-Committee.

The British view on nuclear shipping risks, expressed by Mr D. C. Haselgrove, Under-Secretary, Ministry of Transport, was that many countries lacked the necessary experience to take decisions based on the safety assessment given by the flag country. This could result in restrictions till experience developed. It was, therefore, important that experience was pooled internationally.

Berkeley progresses steadily

London Barring last minute difficulties, the 275 MW nuclear power station at Berkeley (Glos.) will, as expected, go critical in the first half of next year.

Testing of the non-nuclear machinery is expected to be completed by March/April with No. 1 reactor due to be commissioned by June. The second reactor, for which the pressure vessel has been successfully pneumatically pressure tested, should be commissioned during the second half of the year, says a report in 'Power News', a CEGB publication. Civil engineering and mechanical work is almost finished.

The report adds that because of research work done hand-in-hand with construction, graphite laying has been delayed for some months. 'Originally, it was thought that the graphite would expand with time in the reactor', the report continues. 'Now it is thought that some of the graphite blocks must be expected to contract. To counteract this, pins of zirconium metal have been added as stabilisers'.

Finland buys US reactor

Helsinki The Finnish Ministry of Commerce and Industry have signed a contract with General Dynamics Corporation of the US for the supply of a Triga type reactor which will be the nucleus of a new research centre at the Technological Institute at Otaniemi, near Helsinki. Fuel for the Finnish reactor will be drawn from the International Atomic Energy Agency's world 'pool'.

European Atomic Forum to hold Paris congress

Rome A new European association, Foratom (Forum Atomique Europeen) has been established by the national associations for the use and production of atomic energy in France, Belgium, Luxembourg, Italy, W. Germany, Switzerland and the Netherlands (see *Nuclear Power*, April, 1960, p. 115). Its aim is to co-ordinate the activities of the various organizations. One of its first actions has been to decide to hold a congress in Paris in 1962.

New French canning plant

Paris A new plant using sintered ceramics for the manufacture of fuel cans for French heavy water-moderated reactors is to be built near Bordeaux by Compagnie des Etudes et de Realisations de Combustibles Atomiques (Cerca). This is a move in a new direction for the company as previous fuel cans have been made for graphite moderated reactors. Cerca was formed by the Schneider group together with two French chemical firms, Pechiney and St. Gobain.

Second nuclear sub for Britain

London Britain's first nuclear submarine, due to be launched on October 21, is to be followed by a second and larger vessel. An Admiralty announcement says the contract for this has been settled and Vickers-Armstrongs (Shipbuilders) Ltd, have been authorised to put the work in hand. The principal sub-contractors will be Vickers-Armstrongs (Engineers) Ltd, for the machinery and its installation and Rolls Royce and Associates for the nuclear steam raising plant.

The order was forecast in the Government's White Paper on Defence (see *Worldview*, March, p 91). It will differ in that a British-built reactor will be used against the American pressurized-water type in *Dreadnought*. This reactor is not expected to suffer from the noise disadvantage inherent in previous American reactors (see *Cross Section*, June, p 115).

• **United Kingdom** Coal prices have been raised an average of 6s 8d a ton with the average increase per ton for the electricity industry being 5s 1d.

German decision on Euratom reactor may be changed

Brussels The decision by Arbeitsgemeinschaft Kernkraftwerk Stuttgart (AKS) early this year not to go on with its project to build a 150 MW organic-moderated reactor under the US-Euratom programme was the subject of recent talks held here between M. Etienne Hirsch president of the Euratom Commission, and representatives of the German firm. Dr. Joachim Pretsch, West German Atomics Ministry, was also present.

• **United Kingdom** The UKAEA has withdrawn its 1957 offer to Swaziland, Kenya, Uganda, Tanganyika and British Guiana to buy uranium on a ten-year contract from the coming into operation of a mine.

• **Austria** The first core loading of 36 fuel elements to power the Astra reactor at the Austrian Nuclear Reactor Centre has been delivered by Texas Instruments Inc. of the US.

• **France** The French budget contains proposals for an increase of 36% in the amount to be spent on atomic energy this year. The proportion for civil and military use was not revealed.

• **W. Germany** The Kahl power station will supply electricity to the grid this year.

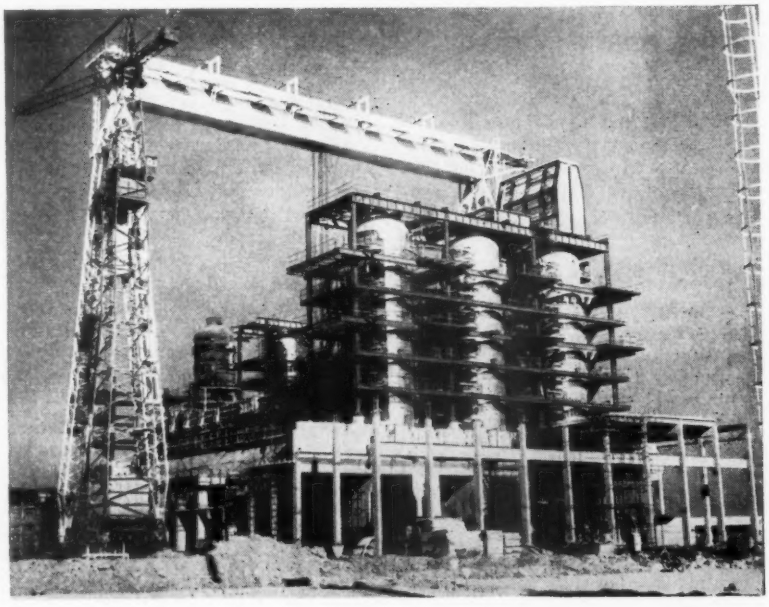
• **IAEA** An expert panel has defined the major problems in the field of third party liability for nuclear ships and will submit its recommendations to the Director General for approval.

Dutch firm may build reactor

Rotterdam After cancelling its order for a 150 MW reactor from the US last year, indications are that the Dutch concern, SEP, may after all, build a nuclear power station. *Nuclear Power* understands that a committee set up by SEP has advocated developing a slurry-type reactor in about ten years. It also recommended that an experimental nuclear-power station be set up to familiarize Dutch technicians and scientists with future problems.

Norwegian nuclear ship rules

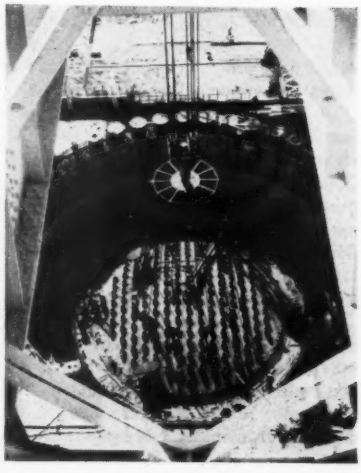
Oslo A set of regulations for the building of nuclear power merchant vessels has been approved by the ship classification body Det Norske Veritas. They follow similar lines to those set out recently by Lloyd's Register of Shipping (see page 92, September).

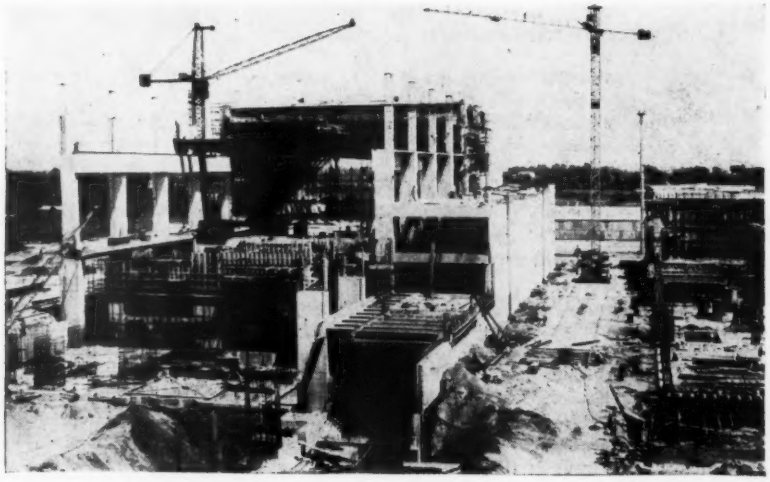


LATINA

Five boilers up, pressure vessel capped

The fifth boiler has been installed at the 200 MW Latina power station, 40 miles south of Rome. Building is moving steadily towards eventual completion of the joint Nuclear Power Plant Co./ Agip Nuclear project in 1962. Our picture (left) shows details of the boiler steelwork, boiler supports and the fifth boiler installed. The top dome for the pressure vessel is shown being installed (bottom left). The last picture (bottom right) shows a general view of the turbine house





• **Italy** The 5 MW heavy water Ispra-1 reactor provided by ACF Industries Ltd. for the Italian National Committee for Nuclear Research has completed its full power acceptance run.

IAEA holds Small Power Reactor Conference

Vienna Growing efforts to simplify and rationalize the mechanical features of reactors and the lowering of costs that could be achieved through simplifying some safety features were two main points that emerged from the Conference on Small and Medium Power Reactors held here recently.

Organized by the International Atomic Energy Agency, the conference lasted for a week and reviewed the present status of nuclear power from technical and economic standpoints. (A full report of the Conference will be given in the November issue of *Nuclear Power*.)

Addressing the final session, **Mr. H.** de Laboulaye, IAEA Deputy Director General for Technical Operations, pointed to the remarkable effort the US had made in this field. Simplification and rationalization of mechanical features of reactors and also of some safety features would lead to a substantial lowering of costs.

Later he said the cost picture presented, though not yet confirmed by experience, appeared definitely brighter than that presented at the 1958 Geneva Conference on the Peaceful Uses of Atomic Energy.

ENRICO FERMI PLANT The latest picture of the American fast breeder reactor after four years of construction. When completed later this year, it will be the largest of its kind in the world (see Worldview, this issue, p. 74)

Halden project extended

Paris The duration of the OEEC Halden reactor project has been extended from three to four and a half years. The project, one run by the European Nuclear Energy Agency, provides for the joint operation of the Halden boiling heavy water reactor by the 12 participating countries in a programme of research and experiment.

The reactor, which has been shut down, was scheduled to start up again around September and the programme on the first natural uranium fuel charge will then be completed. A fuel charge of enriched uranium will be put in in the spring.

Canada helps the UK on steam-cooling

London One of the water-cooled loops of the Canadian NRX reactor at Chalk River is being converted to steam-cooling for the UK to test fuel for steam-cooled reactor systems. 'We have dropped our work on the SCHW system and are actively collaborating with the UKAEA on the steam-generating reactor', Mr. W. B. Lewis, vice-president, Research and Development, Atomic Energy of Canada Ltd, told *Nuclear Power*. 'We are also interested in fog-cooling', he added. (This was described in *Nuclear Power*, August, p 68–73.)

OVERSEAS

Tenders soon for Indian Station?

New Delhi After a comparatively quiet period, interest in building India's first civil nuclear power station has quickened with the news that invitations to tender will probably be issued soon. This follows the recent statement by Prime Minister Nehru that five countries are actively interested in gaining this export order. These are France, the UK, Canada, the US and Japan.

With only one other possible reactor export a short-term possibility—that to Brazil — competition is expected to be extremely keen. The Japanese First Atomic Power Industrial Group (FAPIG), for instance, have already said they will cooperate with the GEC over building the reactor. The Group is also reported as saying that tenders were expected to be invited soon.

However, a GEC spokesman in London says that no invitations to tender had yet been received. But if the GEC were to obtain the contract, it was quite likely that the company, who had an agreement with the FAPIG, would co-operate with them. But it was premature at this stage to discuss such items and it was certainly not possible to say what share of the cost of the project would be supplied by the Japanese group.

In an earlier announcement, Mr Nehru said that the 300 MW station would be built on the west coast, at Tarapore in Maharashtra State. It would have two reactors of 150 MW each (see *Worldview*, May, p 86 and July, p 65) and would begin operating in 1965.

He later added that the Government was considering building two more nuclear stations, each of 150 MW, with the possibility of their capacity being doubled at a later date. He stressed the need to produce plutonium, for 'its production is essential to enable the country to set up breeder-stations using thorium which we have in ample measure'.

One of the further stations India may build could well be in the State of Madras as the state legislative assembly was told recently by its Minister for Electricity, Mr V. Ramiah, that the Indian Government was actively considering this possibility.

Go slow urged for US ships

Washington A call for a modest, long-term plan for merchant ship nuclear propulsion until its economics are definitely known is recommended to the US Maritime Administration. It is based on a report, 'A Proposed Program for Maritime Administration Research', issued by the Maritime Research Advisory Committee of the National Academy of Sciences—National Research Council.

The report advocates caution until the economics of nuclear power offer more definite promise of improving the competitive position of the US merchant marine. It adds that after knowledge is gained from the *Savannah*, a second ship should be considered. But this should only be done if by that time, nuclear power had advanced to a point where a new and more promising approach could be made.

The Maritime Administration, the report concludes, should cooperate with other groups interested in supporting long-range development of radically new and improved nuclear propulsion machinery. Meanwhile, the *Savannah* should be used to gain as much experience as possible.

• **United States** A caesium cell thermionic converter has produced 90 watts of electric power directly from the heat of nuclear fission, General Atomic Division of General Dynamics has announced.

• **Indonesia** A research reactor is to be built near Djakarta with Soviet aid. Work is to start next year.

• **Argentina** Five tons of uranium are to be exported to W. Germany, the National Atomic Energy Commission has announced.

• **Canada** Canada's fifth research reactor, ZED-2, has gone into operation. It will be used for testing uranium fuels.

• **United States** Work on the buildings at the Big Rock Point 75 MW direct cycle forced circulation BWR has started.

• **Japan** Fuji Electric Mfg. Co. is to build a natural uranium, gas-cooled, graphite moderated sub-critical assembly at the First Atomic Power Industry Group's research centre at Takeyama.

• **India** Inventions in the nuclear field will no longer be patentable if an amendment to the Atomic Energy Act is passed.

• **W. Germany** The Congress of the International Law Association in Hamburg recommends that all nuclear inventions should be published and made readily available.

Dim uranium prospects for New Zealand

Wellington The UK Atomic Energy Authority has now withdrawn from a 'top-secret' agreement with the New Zealand Government to investigate possible uranium deposits in the country. This was because New Zealand had no known deposits which could be exploited economically, the Minister of Mines told Parliament.

An Authority geologist had spent more than a year investigating the resources. Prospects were not hopeful for the next ten to twenty years and his report was most discouraging, said the Minister, Mr. Frederick Hackett.

The reason for the agreement being kept secret were not given. But *Nuclear Power* understands that the AEA requested it as it conducted the investigation at a time when supplies were assured and when other countries had better claims on AEA resources.

Japan orders GE research reactor

Washington The first in the new series of research reactors for Japan is to be a direct cycle boiling water plant. This is to be supplied to the Japan Atomic Energy Research Institute by the US General Electric's Atomic Power Equipment Department. The 12·5 MW plant will be used for research and development as well as for power production. It is scheduled to go critical early in 1963 and will be located at Tokai-Mura.

Earlier this year (see *Worldview*, June, p 91) it was announced that Japan would build three new research reactors, bringing to five the number fuelled with US material.

General Electric Japan Ltd is to be the main contractor for the research reactor. Nippon Atomic Industries Group will supply some components and services as subcontractors.

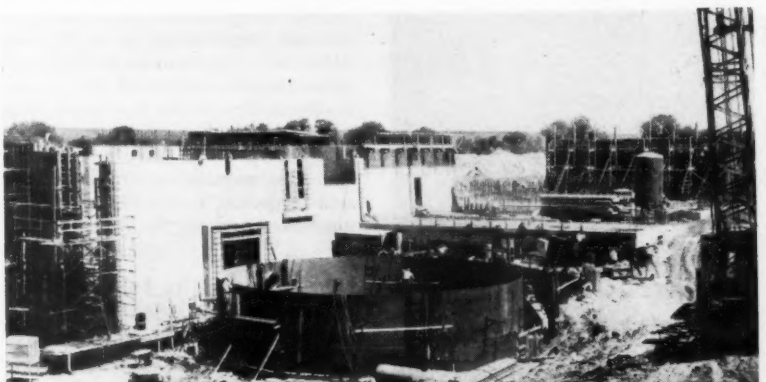
The Japan Atomic Energy Research Institute has three research reactors at the moment: the 50 kW JRR-1 which went critical in 1957; the 10 MW JRR-2 scheduled to go critical this year and the 10 MW JRR-3 which is expected to go into operation early next year.

Humboldt Bay costs rise

San Francisco Revised informal cost estimates of the Humboldt Bay advanced boiling water nuclear power plant have been given by the Pacific Gas & Electric Co of San Francisco. They were issued in answer to an AEC request in August.

The project cost is given as $20·6 million against $M19·5 and the first core fuel assemblies cost at about $2,638,000. The estimate of annual operating costs for the first five years the plant is in operation, including fixed charges, fuel, operation, maintenance and general expense and additional insurance, is given as follows: 1st year—$3,958,000; 2nd year—3,901,000; 3rd year—4,698,000; 4th year—3,496,000 and 5th year— 4,001,000.

The 50 MW reactor is scheduled for completion late in 1962. The reactor contractors are the General Electric Company, California.



PATHFINDER CONSTRUCTION Working two shifts a day, welders have completed the four courses of formed steel plate for the 66 MW Pathfinder reactor containment vessel. Our picture includes the walls for the turbine building (left) and the water treatment building (right)

WORLDVIEW

Canadian-US move on heavy water reactors

Ottawa One of the features of the recent Canadian-US agreement on further co-operation in developing heavy-water moderated reactors (see *Worldview, Briefs*, September, p. 89) is the mutual use of pertinent research and development facilities.

This agreement also covers the exchange of detailed information; close co-operation in research and development work and provision for the transfer of certain materials. The programme extends through the estimated five years of research and development of the Canadian CANDU reactor and for at least five years after its initial operation. A joint technical board is to be established to advise Atomic Energy of Canada Ltd and the USAEC on the overall progress of the programme and future requirements.

Canada's programme so far covers the building of a 20 MW power station (NPD) and the 200 MW CANDU station. A study is being made of a prototype 40 MW organic cooled, water-moderated reactor. The US is building a prototype 17 MW (Carolinas Virginia) heavy water station; the PRTR, a heavy-water moderated plutonium re-cycle test reactor and a heavy water components test reactor (HWCTR). Research is under way on a prototype 50 MW gas-cooled reactor.

Yankee PWR goes critical

Rowe, Mass. The latest US nuclear power plant to go critical, and the first to be completed under the USAEC's Power Demonstration Reactor Programme, is the Yankee Atomic Electric Company's 136 MW reactor near here. Routine full power operation of the pressurized water reactor is scheduled to begin later this year.

Preliminary construction work on the $M57 plant began just under three years ago, in October 1957, and it was completed on schedule on July 7, this year. Criticality was achieved six weeks later. Main contractors were Westinghouse Electric Corporation and Stone & Webster Engineering Corporation, Boston.

The Yankee Atomic Electric Company's power station soon after it went critical on August 19 (see story above)

AEC to make New Production Reactor fuel

Washington Because prices quoted by private industry were substantially above the cost of production in AEC facilities, the fuel element billets for the New Production Reactor (NPR) are to be made by the AEC. In its announcement, the AEC said the prices quoted by four firms 'exceeded by a substantial margin, the cost of producing these billets in AEC facilities. The AEC costs were adjusted to include costs not normal to government operations but common to commercial enterprises'.

Boiling water reactor superheat study for US AEC

New York Atomics International is to conduct a preliminary study of a 300 MW boiling water reactor nuclear power plant with nuclear superheat for the US Atomic Energy Commission. The reactor will use zirconium-hydrid as the moderator in a superheater and slightly enriched uranium as the fuel. Water would be the coolant in the boiler and steam the coolant in the superheater region.

The study will be basically a survey to assess the potential of zirconium-hydrid as a moderator for boiling water steam superheat reactors.

New test facility for US firm

New York A special nuclear fuel test loop for extensive irradiation tests of prototype fuel for the 40 MW, high temperature gas-cooled reactor being built for the Philadelphia Electric Company, is to be built by the US General Electric Company for General Dynamics Corporation.

The loop will be helium cooled with coolant temperatures up to 1400°F, pressures up to 350 lb/in² and coolant flow at the rate of 0·15 per second or higher.

• **S Rhodesia** Uranium ore produced in the first seven months of this year totalled 298 tons worth £4162.

• **Australia** Large undiscovered uranium ore reserves still existed in Australia and the Government was offering rewards for discoveries in anticipation of future demand, Senator Spooner stated recently.

• **United States** Commonwealth Edison is asking the AEC for a licence to operate the Dresden station until May 1996.

Further appeal against Enrico Fermi decision

Washington The Power Reactor Development Company has lodged an appeal with the Supreme Court against the Court of Appeals' decision that the AEC was not justified in issuing a provisional construction permit for the Enrico Fermi 100 MW fast breeder nuclear power plant. (See *Worldview*, September, p 89 and July, p 66). This follows a similar appeal by the USAEC.

The US Court of Appeals in June held that the AEC, from the standpoint of public health and safety, was not justified in issuing the provisional construction permit. The Supreme Court is at present in summer recess and will not re-convene until October.

Japan's new power programme

Tokyo A programme to provide 1000 MW of nuclear power by 1970 has been drafted by the Japanese Atomic Energy Commission. It is based on the assumption that nuclear power generation will become economically competitive by that time.

It recommends that this programme should be expanded to 5000 MW–8000 MW in the next ten years after 1970 and that foreign techniques should be introduced to help Japanese engineers. It also says that a nuclear powered ship should be built by 1970 in order to gain construction and operating experience.

The programme is being considered by a committee of experts and when approved, will replace the original programme drawn up in 1956.

Australian reactor named

Sydney The second Australian reactor now under construction in the US, is due to be installed at Lucas Heights early next year. It is to be called Moata, an aboriginal name used to describe instruments for making heat. The reactor, an Argonaut type, will be used in conjunction with Hifar, Australia's first research reactor, to carry out physics studies of nuclear materials and reactor cores.

MARINE REACTOR ASSEMBLY A General Atomic staff member loads a full channel containing uranium - aluminium foil into the low power assembly developed to provide physics data for the development of the Maritime Gas - Cooled Reactor project

Sodium Reactor Experiment re-starts

Canoga Park, Calif. Operation of the Sodium Reactor Experiment (SRE) for the AEC has been resumed, using a second core of thorium-uranium alloy fuel elements. Atomics International say 31 fuel elements were inserted in the core to bring the reactor to criticality.

The 6 MW SRE is operated by Atomics International as part of the AEC's programme to develop economical nuclear power. It is being used to advance the fuel element development programme for sodium-cooled reactors and has been operated on the first fuel loading (seven-rod cluster type elements of unalloyed uranium metal) for more than two years.

This new start-up is the first time the reactor has been operated since July 26, 1959, when parted fuel elements were observed. During modifications made while the reactor was shut down. 16 graphite moderator cans were replaced and remote inspection of the entire core structure was completed.

The fuel element damage occurred when the coolant passages in the reactor were clogged by the inadvertent introduction of tetralin. This caused overheating and subsequent failure of the fuel element cladding.

• **Australia** The Western Australian port of Geraldton will probably be the first town in Australia to install a nuclear plant to convert salt water to fresh water, says Professor J. Baxter, chairman of the Australian Atomic Energy Commission.

• **United States** The AEC has reduced the price of its carbon 14 by 27%, effective July 1.

• **Puerto Rico** A pool-type, 1 MW research reactor at the Nuclear Centre here has gone critical. It was designed and installed by AMF Atomics.

• **Canada** Eldorado Mining and Refining Ltd's mine has been closed down.

Research into low-cost steels for power reactors

New York New high-strength, low-cost steels for high temperature use in nuclear power reactors are being developed by Atomics International and the United States Steel Corporation. The programme involves alloy modifications to low-cost chromium-molybdenum steels to increase their high temperature strength and corrosion resistance to liquid sodium.

Fuel for US high temperature gas-cooled reactor

Philadelphia The first of 300 fuel moderator loadings for a critical assembly to be used with the design and construction of the high temperature gas-cooled reactor project to be owned and operated by the Philadelphia Electric Company have been shipped. The order was received by the Nuclear Materials and Equipment Corporation from General Dynamics Corporation, the principal contractors for the HTGCR. The fuel-moderator loadings contain highly enriched uranium and, in some instances, thorium carbide fuel materials dispersed in a graphite matrix.

GE to build prototype BWR

New York The single-cycle forced circulation boiling water reactor AEC prototype nuclear power plant near Los Angeles is to be designed and built by the US General Electric Company. The plant is to be operated by the Los Angeles Department of Water & Power and the Pasadena Municipal Light and Power Department. The GEC Company will provide the first fuel load and provide operator training facilities.

US mobile reactor success

Washington Plans are now being made for the operating of a mobile low-power nuclear power plant by the AEC. This follows the successful full power operation of the Gas Cooled Reactor Experiment at Idaho late in July.

The reactor, known as GCRE-I, was operated at 1850 kWt for 48 hours and is a step towards US development of a direct-and-closed-cycle gas-cooled nuclear power plant. This system has been under development for nearly five years.

GCRE-I is part of a programme to provide a mobile nuclear power plant for the Department of Defense. This is to be transportable in four packages totalling less than 38 tons and combines the gas-cooled system with a direct-and-closed-cycle gas turbine-driven power conversion system.

US and Canadian views on small reactors

Ontario Closely following a report prepared for Atomic Energy of Canada Ltd saying that a small nuclear power plant in the Arctic would be more expensive than an oil-burning plant is the news that the US is to build a small nuclear plant in the Antarctic.

The Canadian report was prepared after studying small US reactor types using enriched uranium as fuel. It was compared with an oil-fuelled electricity and heating plant of the same capacity—2 MWe and 17·5 MWt. The annual cost of operating the nuclear plant would be 22% greater, said the report.

Meanwhile, the Martin Co of the US is to design a 1·5 MWe reactor for McMurdo Sound in Antarctica. It will be a pressurized water type, moderated and cooled with light water. It will be in operation by early 1962 and is the first of several plants authorized by Congress.

• **Argentina** Isotope imports in the first seven months of this year were over 7·5 million millicuries. The leading source was Canada.

• **Japan** The Tokyo Institute of Technology has ordered an enriched uranium light water type sub-critical assembly from Mitsubishi Atomic Industries Inc.

• **Japan** The Atomic Fuel Corporation plans to produce 10 tons of natural uranium during the 1960 financial year.

• **United States** Northern States Power Company has received a permit for the building of a 203 MW (thermal) controlled recirculation boiling water reactor on a site near Sioux Falls, South Dakota.

AECL reports to Canadian Parliament

faith in heavy water reaffirmed

CANADIAN HOPES for the heavy water moderated power reactor have always been high and must now have been reinforced by the recent agreement signed with the United States. This provides for an expanded programme of co-operation in a field in which Canadians expect to eventually fuel their power reactors for about 1 mill/kWh. As a sign of its interest, the AEC is to spend an extra $M5 on research and development which will be specifically directed towards heavy water power reactors to be built in Canada.

The four specific power projects at present being undertaken by Atomic Energy of Canada Ltd (AECL) are described in its recent report to the House of Commons Special Committee on Research. These are the Douglas Point Generating Station which includes the CANDU reactor; the Nuclear Power Demonstration Station, NPD-2; an organic-cooled heavy water moderated reactor experiment, OCDRE, and the study of small nuclear power units for possible application in remote regions. The OCDRE, the government agency says, will probably be the next major project undertaken and the first at the new Whiteshell Nuclear Research Establishment now being built.

The Douglas Point station, which will be the first Canadian full-scale nuclear power plant, is in Ontario where at present the southern system of the state's Hydro-Electric Power Commission is now generating electricity from US coal at a cost of 5–6 mills/kWh. When this 200 MW station comes into operation in mid-1964, it is expected to produce power at between six and seven mills per kilowatt hour, depending on the actual interest rate during construction and the lifetime interest rate in effect when the station is built. Later versions of this design are expected to give power for less than 6 mill/kWh.

CANDU advances

During 1959, Mr W. B. Lewis, Vice-President, Research and Development, points out, great advances were made in the CANDU design. The overall plant efficiency was raised to 29·1% and the anticipated fuel burn-up to 9750 megawatt days per tonne of uranium. In combination, this reduced the anticipated fuel cost to about 1 mill/kWh, if fuel fabrication costs were brought down as expected by the present development programme.

NPD-2, with an output of 20 MW, is the prototype for larger stations and is expected to be operating by mid-summer, 1961. It will not produce economical electric power but is expected, however, to demonstrate the reliability of operation of the heavy water moderated natural uranium reactor, the economics of the fuel cycle and provide training for operators for CANDU.

POWER PROJECTS

1. NPD (Nuclear Power Demonstration)—20 MW
2. CANDU (Canadian Deuterium Uranium)—200 MW
3. OCDRE (Organic Cooled Deuterium Moderated Reactor Experiment)
4. Small nuclear power units

PROGRAMME BASIS

Heavy water moderated reactors because :

1. Canadian experience
2. Best for Canadian conditions
3. High neutron economy
4. Natural uranium fuel
5. High fuel burn-up
6. No fuel reprocessing
7. Expected CANDU power cost 6–7 mills/kWh

In the medium-sized range, 50–150 MW, the heavy water moderated reactor with an organic coolant is said to hold considerable promise. The OCDRE project is a result of this thinking and is being undertaken with the object of meeting the requirements of smaller utilities. Its present status consists of a contract with the Canadian GEC Ltd for a phase of development work coupled with preliminary designs. Once approved, it will be built at the Whiteshell Research Establishment and initial field work could start in the summer or autumn of 1962.

Work on very small units has been mainly in the form of a study of the data available in the United States. A contract has been placed with the Canadian Westinghouse Co. to review all pertinent information and to make a detailed assessment as to the application of such systems in the Canadian North.

Trombay reactor

Overseas, the major Canadian project has been the well-known Canada-India Reactor (CIR) at Trombay which went critical recently. This is modelled on the NRX (National Research Experimental) research reactor at Chalk River but modified to meet Indian conditions of cooling water and to include improvements based on NRX experience. It is the largest research reactor in Asia.

Work on other designs of nuclear power plant which use heavy water as a moderator have proceeded. A study, in collaboration with Harwell, on a heavy-water moderated gas-cooled reactor was discontinued when it was decided that it could not compete economically with CANDU. A study using dry steam was also abandoned for the same reason.

The latest investigation is on the use of wet steam. This work on a steam generating reactor is being done in co-operation with the UKAEA Industrial Group. In addition, there is a growing interest in spray-cooled reactors.

Fuel research

Major research programmes are being carried out on uranium dioxide. Work to date has reassured designers that there is no cause to worry about excessive gas pressure within the element sheathing. Research is also being carried out on fuels for later charges for NPD-2 and CANDU. In one series of experiments, swaging of uranium oxide powder in Zircaloy tubes was carried out and the results, while promising, show that more work is required before swaged fuel will be considered for NPD or CANDU.

Plutonium fuels are also being investigated and the emphasis is now moving towards plutonium oxides which might be mixed with uranium oxide. A new laboratory for this work is under construction. Aluminium-plutonium alloys have also been made and tested successfully in the NRX research reactor.

Work is going ahead on the search for better zirconium alloys not only for the CANDU type of reactor but also for high-temperature steam-cooled reactors. To date, several promising leads have been followed but it is still too early to make any predictions on the ultimate success of the programme. The effect of irradiation on the swelling of beryllium is being studied at Chalk River. At the Canadian Westinghouse Co. in Hamilton, beryllium is also being investigated with the emphasis on determining reasons for the low ductility

This review of all known radiation accidents indicates that, with constant care, serious incidents in future atomic energy activities are unlikely

Nuclear accident survey

by J. SPENCER BURKETT, FLA,
Assistant Editor, 'Nuclear Power'

THE PROBABILITY OF a serious radiation accident is considered to be extremely small, in spite of the enormous potential hazard that could occur with release of fission products. Reactors and associated equipment are so designed to prevent this happening; the more serious the accident, the greater the combination of unusual circumstances (*1*).

Nevertheless, accidents are always possible, particularly those associated with improper design, materials defects, instrument failure and, the most common category, human error. A relatively minor incident, although confined to a small area, often represents loss of man-hours, increased operation costs, and loss of research and development time.

The systematic reporting of accidents provides a valuable body of data to designers and health physics administrators in their attempts to create even greater safety. The efforts of the USAEC in this field are particularly thorough (*2*) (see Table 1) and it is to be hoped that other countries will follow suit. So far only the most serious incidents are published; those of lesser significance can be of equal value in a world that is turning more and more to the application, not only of nuclear energy, but also of radiation techniques.

REACTOR INCIDENTS

Canada

The Canadian 30 MW NRX reactor accident (*3*) in December 1952, which caused severe damage, resulted from a concurrence of mechanical defects and operating errors. During preparations for experiments at low power, three to four bypass valves on the shut-off rod air system were opened by mistake, thereby causing three or more rods to rise whilst the reactor was shut down. All valves were then rectified and air pressures checked; the rods should have dropped back but did not.

Added to this, following a wrong instruction, the shut-off rods were raised, causing a power surge. In spite of subsequent correction, the rods remained up and the power level continued to rise. As an emergency, the heavy water was dumped to the storage tanks below and, within 60 seconds, the power was back to zero.

During the surge, the uranium metal melted, rupturing the aluminium canning and the tubes separating the heavy water, air and cooling water systems. As a result, some 10,000 curies of fission products were carried by a flood of one million gallons of cooling water into the basement. Meanwhile, fused masses of highly irradiated uranium and uranium dioxide were left inside the calandria, and the core vessel and calandria tubes were severely damaged.

Whilst the runaway caused a major interruption to work, it was small compared with what might have happened if one more shut-off rod had been up. In such an event, large amounts of fission products would have contaminated a wide area. Although the radioactive contamination prolonged repair work, at no time did it constitute an uncontrolled danger. Neither were there cases of harmful exposure.

Improvements in decontamination facilities that followed the NRX accident were a great help during the clean-up that followed the contamination of the NRU 200 MW reactor in 1958 (*4*) Since its first operation in November 1957, a number of teething troubles had arisen. Apart from the unsatisfactory operation of the coolant flow-rate meter for individual fuel rods, there had been a high incidence of canning failures and the first loading fuel elements were considered unsuitable for long-term use.

After a week of steady operation, an excessive power rate-of-rise caused an automatic shut-down. Since no evidence could be found to explain this, the reactor was restarted, only to be met with another shut-down. This was accompanied by alarm signals indicating unusual conditions in the reactor, primarily very high radioactivity in the coolant circuit.

Three rods displayed a high level of activity and two were removed by the charge machine. Attempts to move the third—a badly damaged rod—failed; consequently, non-standard methods were adopted during which the heavy water coolant drained from the removal flask into the reactor. The rod melted and was torn into several

FEW ATOMIC ACCIDENTS

Despite the large number of reactors of all types now operating, and the even greater number of radiation sources that are being used, there have been relatively few serious accidents.

Of the accidents listed, the greater number are relatively minor ones resulting from human error or carelessness, or from mechanical faults. More serious are those involving critical mass excursions associated with small experimental facilities.

The more sophisticated reactor designs, in general, have given little trouble apart from various anticipated mechanical faults. There have been, however, a few serious incidents: Canada—two, UK—one, France—one, and Yugoslavia—one. Less serious accidents have involved two US reactors, the Russian G-1, in which two people received excess dosage, and the Japanese JRR-1.

TABLE 1 *Workers affected: USAEC, 1943–1958 (2)*

injuries from all causes	5651
radiation injuries (0·6%)	35
deaths from all causes (falls 44; electrical shock 35)	202
radiation deaths	4
man-days of potential exposure	over 2 million hours
workdays lost from all causes (0·3%)	nearly 700,000
workdays lost from radiation exposure (0·01%)	under 32,000

pieces, one of which dropped onto the charge floor and burned in the open. Another piece dropped to the bottom of the reactor. Although the burning uranium was extinguished in 10–15 minutes, the top of the reactor was badly contaminated with UO_2, in addition to serious contamination through the entire reactor area.

In a radiation environment in excess of 1000 *r*/h, 40 men working for 1½ minute periods, disposed of the uranium debris and no person received a dose higher than 5·3*r*. The clean-up occupied 600 men for over two months but by the end of August, the reactor recommenced operation.

Some interesting problems were resolved by this incident. One in particular was the need for detailed planning and organization to cope with an emergency situation. Careful control of staff exposure times, coupled with frequent bio-assay tests played a major role in preventing any serious radiation exposures.

France

Teething troubles have also been experienced with the two French heavy water research reactors, EL2 and EL3 (*5*). From 1957 to 1959, EL2 suffered four significant incidents—three canning ruptures and a neutron converter meltdown caused by faulty cooling. It must be pointed out, however, that these were not exactly unexpected because it was the purpose of the reactor to make fuel elements last as long as possible. Nevertheless, some useful lessons were learned and included perfecting procedures for handling contaminated equipment, and improvement of burst slug detection systems.

The only important incident in EL3 took place in 1958 at the conclusion of a full-power testing period when, at a flux of 10^{14}, with the fuel temperature at 400°C, the alarm sounded. Heavy contamination of the primary coolant circuit led to the conclusion that a fuel element had been damaged.

Yugoslavia

One of the most interesting accidents of recent times was that at the Vinca nuclear research centre in Yugoslavia in 1958, when six persons were irradiated by neutron and gamma rays (*6*). Personnel dosimeters, film badges and pocket chambers were completely saturated, leading to the conclusion that the doses received had passed the lethal range. The patients were flown to the Curie Foundation in Paris for radiopathological treatment. The most highly irradiated person died on the 32nd day but the others survived after they had been given bone-marrow grafts.

TABLE 2 *The worst accidents that could happen to US power reactors* (9)

PRESSURIZED WATER REACTORS	
rupture of primary coolant piping or system (with failure of safety injection system or emergency cooling)	SM-1, Shippingport, Indian Point, Yankee, NS Savannah, Saxton, Carolinas-Virginia
meltdown of complete core, or seed elements, or fuel cladding (complete in just over 20 min) dependent on reactor design	
BOILING WATER REACTORS	
boiler explosion, severance of coolant recirculation or bottom inlet lines (with failure of shut-down or emergency cooling system)	Vallecitos, Dresden, Elk River, Pathfinder, Humboldt Bay, Big Rock Point, Bonus (Puerto Rico)
release of water and flash steam (few seconds), or meltdown of cladding (start 8–15 min) and fuel (complete in 24–40 h)	
GAS COOLED REACTORS	
rupture of primary coolant system	EGCR, Peach Bottom, Florida West Coast
metal clad elements will rupture from fission gas pressure; graphite cladding, however, is expected to allow only a small release of fission products	
ORGANIC MODERATED REACTORS	
continuous and uncontrolled withdrawal of control rods during start-up	Piqua
void formation and meltdown of 50% of 6 central fuel elements with release of core fission products (no excessive activity released beyond coolant system with pipe rupture—core meltdown prevented by decay-heat-removal system)	
SODIUM COOLED REACTORS	
failure of control rod thimble in helium region	Hallam
1% cladding failure releases 20% fission gas activity to rod void spaces	
FAST REACTORS	
fuel meltdown not expected—no single failure will result in lowering level of sodium in core	Enrico Fermi

The reactor, which consists of uranium rods in heavy water, contained in a 6 ft × 7 ft tank, was operating at practically zero power. Because of its utilization at a subcritical level, the reactor did not have a protective shield, operation being regulated by changing the heavy water level, with reaction stopped by two cadmium safety rods.

The experiment in progress consisted of neutron flux measurement before and after the addition of a RaBe source. Uncontrolled fission resulted and continued for several minutes before the safety rods had effect. However, gamma irradiation continued. The gamma dose received by the operators varied from 450–1000*r*. The official view was that insufficient qualified staff had been in charge of the reactor and that there had been a lack of vigilance.

The accident did no damage to the reactor or its materials and, in the redesign, a safety interlock system and a personnel shield were installed. Another outcome was the re-enactment of the incident by the IAEA with American and French technicians supervising.

Windscale

The only serious recorded accident in the UK, Windscale, resulted in more than technical improvements (*7*). Apart from building up a considerable amount of information on graphite behaviour and Wigner energy, it triggered off the awareness of public anxiety about hazards connected with atomic energy work. In addition, it demonstrated the inadequacy of the health and safety organization.

POWER EXCURSIONS

In various USAEC critical experiments, a number of power excursions have been recorded that resulted from prompt critical configurations (see Table 3). Of these, 11 occurred at Los Alamos, three at Oak Ridge and two at Argonne.

Up to 1946, it was the practice in these experiments to bring the active material to criticality by direct manual adjustment. Errors in this procedure have resulted in operation by remote control (*24*). The two accidents at Los Alamos (*16*), each of which resulted in a fatality, occurred with the same core.

In the 1945 incident, the assembly was being brought to criticality by hand-stacking tungsten-carbide bricks around a plutonium core. The final brick, that would have made the assembly super-critical, slipped and fell onto the centre of the assembly, thereby making the system super-prompt critical. Despite the hazardous conditions, the operator proceeded to unstack the assembly, during which time he received lethal exposure.

In the 1946 incident, which was in the nature of a demonstration, the same plutonium sphere was being stacked with beryllium shells. The top and final shell, which was being lowered slowly into place, accidentally fell onto the lower hemisphere. A burst immediately occurred and the shell was thrown to the floor. The eight persons present left the room at once, but they all suffered varying radiation

doses although only the man operating the experiment died.

In a more recent occurrence at Los Alamos (*18*) in 1957, the unreflected enriched U-235 metal reactor, Godiva, was damaged beyond repair. This assembly had been used over several years for scheduled prompt bursts. On this occasion, however, the burst was about twelve times the standard excursion. The extra reactivity is thought to have been caused by a shift of part of a nearby mass of graphite and polyethylene that was due to be irradiated. The mass shift acted as a neutron reflector for the metal uranium sphere.

The first accident at Argonne (*14*) resulted from the manual withdrawal of the central control rod from a light water moderated core. The experiment in progress at the time consisted of making comparisons of central control rod worths of different design. Previous calculations indicated that the system would remain subcritical with only the four peripheral control rods in position. On this occasion, the excursion was accompanied by the sound of an underwater shock and by

TABLE 3 These accidents happened

REACTOR INCIDENTS					
Heavy-water-moderated reactors					
Dec. 1952 (*3*) Chalk River	30MW NRX	power surge to 80MW caused by defective shut-off rod system that led to ruptured fuel elements	10,000c of fission products carried to reactor basement by 1M gallons cooling water	Severe damage to reactor core, and other parts	No personnel affected
May 1958 (*4*) Chalk River	200MW NRU	fuel rods damaged—one being withdrawn broke and burnt in open air	Broken rod portion left in reactor and reactor top badly contaminated	Contamination more than 1000r/h	no personnel affected
Oct. 1958 (*6*) Vinca, Yugoslavia	U rods in D_2O cylindrical tank—unreflected	introduction of RaBe source, together with elevation of D_2O level, led to excessive neutron and gamma radiation			6 persons affected 1 death—1000 rem 4 600–1000 rem 1 400 rem
1957–1959 Saclay (*5*)	EL-2 EL-3	mostly routine incidents: water and helium leaks, fuel element cladding failures, faulty cooling of neutron converters			no personnel affected
April 1958	EL-3	damaged fuel element led to considerable contamination of primary coolant circuit			
Gas-cooled graphite-moderated reactors					
Oct. 1957 (*7*) Windscale	Pu producing	nuclear heating for Wigner release applied too soon and too rapidly—failure of one or more cartridges led to oxidation, spread of fire affecting 150 channels	both reactors closed down	I-131 released to environment—milk distribution 200 sq. miles stopped	no personnel affected
Sodium-cooled reactors					
July 1959 (*8*)	SRE	12 fuel elements ruptured—stainless steel cladding melted	During removal of fuel elements, pieces of slug spilled on core top		no personnel affected
Homogenous reactors					
Feb. 1960 Oak Ridge	HRE-2	hole burned in wall of inner core tank (2nd in two years)	repair in progress		
Other reactors					
Dec. 1959 Japan	Japanese research reactor No. 1	Excessive radiation due to radioactive Mn-56 spilling on extraction from experimental hole			

	REACTOR OR ASSEMBLY		INCIDENT			
DATE, PLACE	GEOMETRY	ACTIVE MATERIAL	CAUSE	TOTAL FISSIONS	PHYSICAL DAMAGE	PERSONS AFFECTED BY RADIATION
CRITICAL ASSEMBLIES						
uranium/water solutions						
Dec. 1949 Los Alamos	'water boiler' reactor 12in. dia. ss sphere graphite reflected	1kg U-235 in uranyl nitrate	during control rod testing—rods removed manually	$3–4\times10^{16}$	none	1: 2·5r
May 1954 (*11*) Oak Ridge	Annular cylindrical containers 10in., 2in. dia., unreflected	18·3kg U-235 in UO_2F_2	critical properties expt.—tilting of inner cylinder	1×10^{17}	none	none
Feb. 1956 Oak Ridge	unreflected 30in. dia. tank	27·7kg U-235 in UO_2F_2	reactor stability measurements—wave motion created by falling cadmium scram	$1·6\times10^{17}$	cylinder bottom warped	none
plutonium/water solutions						
Nov. 1951 (*12*) Hanford	unreflected 20in. dia. Al sphere 93% full	1·15kg Pu in plutonium nitrate	container geometry expts.—control rod run out too fast	8×10^{16}	none	none
water moderated systems						
June 1945 Los Alamos	polyethylene core surrounded with uranium cubes in water tank	35·4kg U ~83% enriched	critical mass expts.—water seeped between blocks	$\sim3\times10^{16}$	none	3: dose varied: 7·4—66 rep
Feb. 1951 (*13*) Los Alamos	two uranium cylinders 93% enriched	24·4 and 38·5kg	critical separation expt.—scram increased reactivity	10^{17}	slight oxidation	none
July 1952 (*14*) Argonne N.L.	U-235 oxide imbedded in strips of polystyrene plastic	6·8kg	reactor mock-up expt.—manual withdrawal of central safety rod	$1·22\times10^{17}$	plastic destroyed	4: dose varied: 9–136 rep
July 1954 (*15*) Argonne, Idaho Testing Area	Borax reactor aluminium-uranium in 4ft semi-buried tank	U-Al plates clad with 0·020 Al	excess reactivity studies—estimate of expected excursion too low	$4·68\times10^{18}$	reactor destroyed	none
uranium or plutonium in air						
Los Alamos (*16*) Aug. 1945	Pu core—nickel coated tungsten carbide reflected	6·2kg	hand stacking reflector accident	10^{16}	none	2: 1 death—800 rep 1 20 rep
May 1946	beryllium reflected	6·2kg	hand stacking reflector accident	$\sim3\times10^{16}$	none	8: 1 death—900 rep
April 1952 (*17*) Los Alamos	Jemima—cylindrical unreflected U-235 assembly	92·4kg U 93% enriched	calculation error	$1·5\times10^{16}$	none	none
Los Alamos (*18*) Feb. 1954	Godiva—bare U-235 sphere no reflexion	53–54kg U 93% enriched	control rod incorrectly operated	$5·6\times10^{16}$	slight warping	none
Feb. 1957	added reflexion	53–54kg U 93% enriched	shift of expt.	$1·2\times10^{17}$	warping, oxidation	none
other systems						
Feb. 1945 (*19*) Los Alamos	Dragon reactor	UH_3 pressed in styrex	prompt power excursions reflector added—source too large	$\sim6\times10^{16}$	UH_3-styrex cubes swollen	none
July 1956 (*10*) Los Alamos	honeycomb U-235 foils graphite moderated	58kg U 93% enriched	geometry simulation—too rapid assembly	$3·2\times10^{16}$	none	none
PROCESSING CRITICALITY INCIDENTS						
June 1958 (*20*) Y-12 Plant, Oak Ridge	55-gallon processing tank	2·5kg U-235 in $UO_2(NO_3)_2$	process solution combined with wash water	$1·3\times10^{18}$	none	8: dose varied 30—461 rem
Dec. 1958 (*21*) Pu Processing Plant, Los Alamos	processing tank	3·27kg Pu in $PuO_2(NO_3)_2$	agitator created a critical geometry	$1·5\times10^{17}$	none	3: 1 death dose varied: 53, 134, 1200 rem
Oct. 1959 (*22*) Arco Plant,	processing tank	$UO_2(NO_3)_2$ water	process solution siphoned from safe to unsafe geometry	$\sim4\times10^{19}$	none	19: dose varied: 32, 50, and lower

the emanation of a blue light. Although the fuel elements were ruined, no significant amount of fissile material was lost. Four persons were irradiated and the activity in the reactor room was above tolerance for a day. Decontamination was completed by a single application of detergent and water.

The Borax-I excursion at Argonne was an accident only in the sense that it was larger than expected (*15*). Scheduled steady state studies had been completed and, before dismantling, it was decided to force the reactor onto a short period transient to produce a fission yield of a value that would melt about 4% of the fuel plates.

The burst, which followed the rapid ejection of the control rod, completely destroyed the core and ruptured the reactor tank. Some of the fuel plates, which had suffered very extensive melting, were found up to 200 feet away, and the control rod mechanism, weighing some 2000 lb, was tossed about 30 ft into the air. The experiment was conducted on a remote site, and, in spite of the severity of the explosion, no personnel were affected.

PROCESSING PLANT ACCIDENTS

Two of the incidents at Oak Ridge occurred with aqueous solutions of enriched uranium, and their consequences serve to illustrate what could happen in solution processing operations if certain safety features are violated. In one case, a neutron absorber cylinder, located within the tank of solution, tipped to the side of the outer container and introduced about 2·1% in reactivity (*11*).

In the second accident (*11*), the falling scram, a cadmium sheet, fell into a near-critical shallow mass of solution and set up a wave disturbance. A super-prompt critical geometry of unknown excess reactivity was thereby created. The large volume of solution that was ejected from the cylinder necessitated a great amount of chemical decontamination, but the released activity was relatively short-lived and no long-range radiation problem was created.

The Y-12 accident at Oak Ridge (*20*) occurred in the chemical processing area. It might have been more serious but for the prompt and orderly evacuation plans that were followed. At the time, a number of 5 in. diameter tanks were being leak tested with water and, unknown to the operator, enriched uranium solution flowed from an untested tank into one of the tanks under test, partially filling it. The balance of the void area was filled with water during leak testing. The operator drained the contents of this tank into a 55-gal stainless steel drum, whereupon the level of the enriched uranium solution in the drum built up to a level that initiated a critical reaction. Flow of further water decreased the reactivity, but it was 20 minutes later before the solution become subcritical. There was no damage or contamination and the eight persons irradiated eventually returned to work.

Another processing accident (*21*) which resulted in the death of the operator 36 hours later, occurred in December 1958, at Los Alamos, during separation stages for the purification and concentration of plutonium. Plutonium-containing solids, which normally would have been handled separately, were washed from two other vessels into a larger vessel containing dilute aqueous and organic solutions. After removing most of the aqueous solution, the remaining material, which included nitric acid wash, was transferred to the 225-gal tank in which the accident occurred. This tank already contained caustic-stabilized aqueous-organic emulsion and the added acid is thought to have separated the liquid phase. The power excursion was triggered off when the electrically-driven stirrer started to mix the solutions.

The Arco incident in 1959 (*22*) occurred in a chemical processing plant for used fuel elements from various reactors. The active material involved was stored in a bank of containers in a concentrated form of uranyl nitrate. The solution was inadvertently siphoned into a 5000-gal tank containing 600 l of water. This caused the combined mass to go critical and sufficient energy was created to boil away nearly half of the solution. Because of the thick shielding around the plant, however, beta dosages, received by the 19 persons in the building, were only small and they were all obtained while the building was being evacuated.

The accidents described above emphasize that, in spite of carefully calculated geometries for the safe containment of fissionable materials, inadvertent assembly of such materials during processing can lead to unsafe geometries, releasing a fission yield far greater than can be contained.

NON-CRITICAL ACCIDENTS

Many of the incidents reported in this category (*2*) resulted from human error, a cause difficult to predict and prevent. The importance of correct training in the use of handling of radioactive sources is a particular lesson that emerges. Exposure accidents during the operation of linear accelerators have also happened; through not following the proper drill.

Other accidents stemmed from inadequate radiation measurement, or lack of forethought. In one glove box accident where Sr-90 was being handled, miscalculation of the attenuation by both the glass wall and the gloves led to beta burns. In another, where a plutonium bearing organic solution was being handled, the jamming of a drill caused one glove to be torn.

CONCLUSION

A study of these accidents shows that they will occur as long as designs are imperfect and are constructed and operated by man. It is necessary, therefore, to anticipate such accidents and have ready an adequate plan for early warning, evacuation, health physics, and decontamination (*1, 23*). The hazards report (*9*) (see Table 2.) that is compiled for each reactor is a stage towards such anticipation. Above all, adequate instrumentation and unmistakable alarm signals should be installed wherever necessary. There is no doubt that the lessons learned have already had their effect on the safety design of the new generation of reactors.

References

1. Morgan, K. Z. Symposium on Health Physics, Risø, 1959. 339–378.
2. Summary of accidents and incidents, 1945–1955; Supplements for 1956, 1957. Report TID-5360.
3. Accident to NRX. Reports AECL-232-233.
4. Contamination of NRU. Report AECL-850.
5. Sallingand, P. Reactor incidents at Saclay. *Nucleonics*, **18**, 82–5, March 1960.
6. Yugoslavian criticality accident. *Nucleonics*, **17**, 1959 April, 154–6, *Rev. franç. études Clin. et Bio.*, **4**, 210–225, 1959 (translated: AEC-tr-3774).
7. Windscale. Interim report Cmnd. 302, Oct. 1957; final report Cmnd. 471, July 1958; Committee report on Control of Health and Safety Cmnd. 342, Jan. 1958. HMSO.
8. Dickinson, R. W. Coolant block damaged SRE fuel. *Nucleonics*, **18**, 1960, Jan., 107.
9. Maximum credible accidents, *Tehnical Progress Review on Nuclear Safety*, June 1960, USAEC.
10. Stratton, W. R. Review of criticality accidents (awaiting publication, Pergamon Press).
11. Radiation excursions at ORNL. Report ORNL-2452, 1958.
12. Radiation burst in the Hanford homogeneous reactor. Report HW-24327, 1952.
13. Accidental radiation burst. Report LA-1289, 1951.
14. ZPR-1 accidental transient. Report ANL-4971, 1953.
15. Report ANL-5323, 1954.
16. Radiation doses in the Pajarito accident. Report LA-687, 1948.
17. Report LA-1477, 1952.
18. Time behaviour of Godiva through prompt critical. Report LA-2029, 1956.
19. Report LA-397, 1945.
20. Accidental radiation excursion at Y-12 plant. Report Y-1234; *Health Physics*, **1**, 1959, March, 363–72; *Nucleonics*, **16**, Nov., 1958, 138–40.
21. Nuclear critical accident at LASC, 1958. Report LAMS-2293, 1959; *Nucleonics*, **17**, 1959, April, 107.
22. Nuclear incident at Idaho Chemical Processing Plant, Report IDO-10035, 1960.
23. Exposure criteria for evaluating public consequences of catastrophic accidents, *Health Physics*, **1**, 1958, June, 76–84.
24. Studies in nuclear safety. Report K-1380, 1958.

Nuclear plant for space propulsion

Progress in the USA

THE SUCCESSFUL testing of an experimental core designed for use in a compact reactor has again focused attention on the US space propulsion programmes. It is here that a succession of Snap (Systems for Nuclear Auxiliary Power) devices have been developed; nuclear rocket engines successfully tested and plans made for a test reactor for the nuclear ramjet programme.

Two main points lies behind these developments. The first is that nuclear energy can be superior to chemical energy for long-range propulsion through the atmosphere or outer space. The second is the need for a reliable, compact, lightweight, long-life power source for a satellite.

Nearly five years ago, the USAEC decided to go ahead with formal research programmes to determine the feasibility of nuclear propulsion systems for space vehicles. By 1957, Project Rover (nuclear propulsion by rockets) had been concentrated at Los Alamos and Project Pluto (nuclear ramjet propulsion systems) at Livermore Radiation Laboratory at the University of California.

Much of the Rover work is on solid-fuel, heat-exchanger reactors using uranium-235 as a fuel. In July 1959, came the laconic announcement of the Kiwi-A nuclear rocket engine's 'flightless flight' —a successful full power ground test of a high-power density reactor. Power was provided by the expulsion of hydrogen gas through a nozzle after it had passed through channels, cooling the reactor and, at the same time, being heated.

Kiwi tests

This was followed by the successful test of the next unit, Kiwi-A Prime, this summer. Both reactors have been dismantled in a special Mad (Maintenance, Assembly and Disassembly) shop where the equipment receives a thorough examination. Endurance testing of a third engine, Kiwi-A3, until there is positive evidence of damage, is the next stage. and is scheduled for this autumn after a postponement earlier this year. It again will be dismantled and examined in the Mad shop and will tell Los Alamos men about the next stage in building rockets that will fly. Code names for these rockets have, in fact, been prepared. The first, appropriately enough, is Dumbo. The next is Condor.

There is less news about Project Pluto which aims basically at demonstrating the use of a reactor as the heat source in a ramjet engine. Special test facilities have been built at the AEC's Nevada Test Site and the design and fabrication of the first test reactor, Tory II, is going according to schedule.

US PROJECTS

1. ROVER—nuclear rocket propulsion
2. PLUTO—ramjet propulsion
3. SNAP—systems for nuclear auxiliary power
   - *a.* radioisotope-heated units Snap 1, 3
   - *b.* small reactor-heated units Snap 2, 8, 10

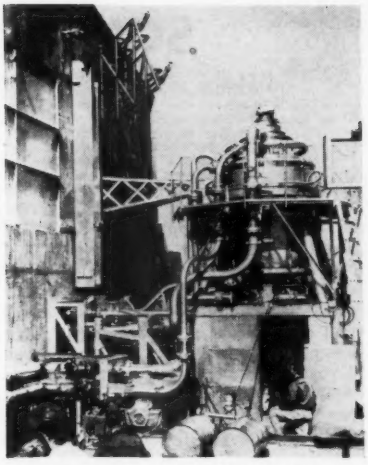
UNDERTAKEN BY

1. Los Alamos Scientific Laboratory
2. University of California, Livermore Radiation Laboratory
3. Mainly *a.* Martin Co Nuclear Division
   b. Atomics International

Snap units

It is in the Snap programme that most new units have been developed and, because of the satellite launchings, where most interest has been focused. The approach has been along two lines: (1) radioisotope-heated units such as Snap 1 and Snap 3; (2) small reactor-heated units such as Snap 2.

Snap 3 was the first complete unit delivered by the Martin Co (which is the contractor for the radioisotope units). This took place in January last year. The unit has a power output of about 3·5 W, weighs four lb and is fuelled by polonium-210. Martin are also working on Snap 1A which has a power output of 125 W, weighs 175 lb and is fuelled by cerium-144. The company has on hand a generator for a telemetry station which is the heaviest of the units, weighing some 1680 lb. However, its power output of 5 W, obtained from strontium-90, can be sustained for at least two years, if not longer.



Appropriately named after a bird that cannot fly, the Kiwi-A, the first of the three US test nuclear rocket engines, is seen being prepared for its successful full power ground test

The latest announced development in the Snap reactor programme is Snap 10, a thermo-electric direct conversion unit only seven inches high, weighing less than 200 lb and producing 300 W. It is one of three systems under development by Atomics International and after start-up, operates without active control systems and has no moving parts.

Experimental reactor

The first of these was the Snap Experimental Reactor, a prototype for the Snap 2 project. This successfully completed a 1000-h. operation under design conditions at a coolant outlet temperature of 1200°F in May this year. It is comparable in size to a five-gallon can, weighs about 220 lb without shielding, and is cooled by liquid sodium. Since the reactor began operating in November 1959, it has produced more than 100,000 kW hours of heat, using enriched uranium as fuel. It will produce 3 kW of heat.

Snap 8 grew out of this and is, in fact, a higher powered version, capable of delivering approximately ten times its power output. None are propulsion systems but are designed to give satellites more than a year's supply of electricity.

The next stage US effort is expected to be aimed at is the use of these Snap units in satellites as TV and broadcast relay stations, and for weather, navigation and communications. For while their power life at the moment is rated at one year, they can be developed to operate for many years. Already there is talk of these units being adapted to provide a portable power plant, easily transportable and a boon where unattended sources of power are required.

SCINTILLATION COUNTERS

A survey by R. B. Owen, B.Sc., AERE Harwell

FOLLOWING THE SURVEY of gas ionization detectors which appeared in the August issue, this review deals with some of the more widely applicable phosphors and photomultipliers used for scintillation counting (*1, 2*). The first table, which is arranged under types of commercially available phosphors, gives the principle physical properties, relevant to counting, the forms available and the names of the suppliers. Where the exact components of the scintillator are variable, e.g. for liquid and plastic scintillators, the properties given can be only approximate. Table 2, arranged under manufacturers, is a selection of current types and makes no attempt to list the complete range of photomultipliers available. The multiplicity of types can be prodigious since many variations are possible, e.g. photocathode response and size, the form of the electron multiplying system, the nature of the secondary emitting surface, the number of secondary emitters, in addition to variations in processing technique and selection after manufacture. Some typical USA and USSR types are described which are not necessarily available from UK agencies, and the data is given so as to provide background to the general literature describing experimental work. Table 3, of scintillation detector assemblies, again under manufacturers, is not exhaustive; it indicates rather assemblies in which the basic components of photocell and phosphor may be combined as a working unit suitable for providing signals to other electronic instruments. The details given in the tables have been supplied by the manufacturers and are necessarily brief. The survey aims at covering the field as widely as possible, leaving the reader to seek more detailed specifications from the companies listed.

References

(1) Owen, R. B.: *Nuclear Power*, **3**, April, 166 (1958)
(2) Gray, A. L., and Loosemore, W. R.: *Nuclear Power*. **4**, Feb., April, May, June (1959)
(3) Borkowski, C. J., and Clarke, P. L.: *Rev. Sci. Inst.* **24** 1046 (1953)
(4) Orphel, T. R.: *Nuc. Inst.* **3** 45 (1958)
(5) Eby, F. S., and Jenschke, K. W.: *Phys. Rev.* **96** 111 (1954)
(6) Storey, R. S., Jack, W. J., and Ward, A.: *Proc. Phys. Soc.* **72** 1 (1958)
(7) Schenk, J., and Neiler, J. H.: *Nucleonics* **12** (4) 28 (1954)
(8) Computed from NBL 325
(9) Murray, R. B.: *IRE Trans. N.S.* 5 **3** 159 (1958)
(10) Fortè, M.: Riso Conference 1958
(11) Palevsky, H., et al.: *Phys. Rev.* **91** 451 (1953)
(12) Hornyak, W. F.: *Rev. Sci. Inst.* **23** 264 (1952)
(13) Owen, R. B., Smout, D. W. S., and Wassen, M. M.: unpublished
(14) Heckman, P. H.: *Naturwiss*, **46** 206 (1959)
(15) Owen, R. B.: *IRE Trans. NS* 5 **3** 189 (1958)
(16) Brooks, F. D.: *Nuc. Inst.* **4** 151-163 (1959)
(17) Hayes et al: *Nucleonics* **14** (1) 42 (1956)
(18) Kinard, F. E.: *Rev. Sci. Inst.* **28** (4) 293 (1957)
(19) Turst, M., and Kallmann, H.: *Phys. Rev.* **97** 583 (1955)
(20) White, C. G., and Helf, S.: *Nucleonics* **14** (10) 46 (1956)
(21) Woulters, L. F.: *Nucleonics* **12** (3) 27 (1954)
(22) Brooks, F. D., Pringle, R. W., and Funt, B. L.: Scintillator Counter Symposium, Washington, 1960 (in press)
(23) Belcher, H.: *Brit. J. Radiol.* 103 (1957)
(24) Sun, K. H., et al: *Phys. Rev.* **95** 600 (1955)
(25) Anderson, D. J., Dracass, J., and Flanagan, T. P.: Inst. and Meas. Conf., Stockholm, 1960 (Sept.)
(26) Ginter, R.: Scintillator Counter Symposium, Washington 1960

TABLE 1 Phosphors for scintillation counting

The photoelectron yield gives the number of photoelectrons which might be expected, per MeV incident particle energy, at the stated energy for the particular type of particle from a 40 μA/lm S11 (Cs_3Sb) type photocathode.

Scintillating liquids and plastics consist essentially of (a) a primary solute; e.g. p-terphenyl PPO (2, 5 diphenyloxazole) or PBD (2-phenyl-5-(4-biphenylyl)-1,3,4-oxadiazole), usually used at concentrations of 3-8 g/litre; (b) a secondary solute, or wavelength shifter, which shifts the wavelength of the fluorescence to suit the photocell response, e.g. PPO, diphenyl stilbene, α NPO (2 - (1 - naphthyl) - 5 - phenyloxazole), diphenylhexatriene, POPOP (1, 4-bis 2-(5-phenyloxazolyl)-benzene) or BBO (2, 5-di-(4 biphenylyl) oxazole, usually used at 0·03–0·1 g/litre; (c) a solvent, e.g. toluene, xylene, 1-4 dioxane, etc., or a mixture of these to which a quantity ~25% of naphthalene may be added to assist energy transfer to the solute. A wide choice of the components of a scintillation solution is thus available to suit the particular circumstances of the measurement, e.g. limitations on solubility, miscibility, etc. Typical solutions given in the table have been obtained from the literature and do not necessarily conform to the types sold under proprietary titles for which somewhat different photoelectron yield values may be claimed. An attempt has been made to classify more in terms of application.

TYPE	PRINCIPAL PHYSICAL PROPERTIES	FORMS AVAILABLE. PROPRIETARY TITLES. SUPPLIERS.
NaI-Tl	Density 3·67 Refractive index 1·77 Photoelectron yield* per MeV:—3000 (electrons) (1), 4300 (protons), 2400 (5 MeV alpha) (2) Light pulse width depends on dE/dx** (3) Main decay time 0·25 μ s Gamma energy (keV) 20 33 33 50 100 200 500 1000 2000 5000 10000 Gamma absorption coeff. (cm^{-1}) 61 14 110 37 6 1·15 0·33 0·21 0·155 0·128 0·135 P/T*** (1½ in. dia. × 1 in.) Experimental 1 1 1 1 0·98 0·925 0·43 0·23 0·15 (3 in. dia. × 3 in.) Experimental 1 1 1 1 0·98 0·925 0·650 0·415 0·26 Typical applications: gamma ray detection and spectroscopy. * Photoelectron yield per MeV for good optical coupling to 40 μA/lm cathode. ** dE/dx=energy loss of existing particle per unit path length in phosphor. *** Ratio of counts in the 'photo peak' of pulse amplitude distribution to total counts.	Single crystals (up to 9 in. dia × 9 in. reported). Damaged by moisture, normally purchased in hermetically sealed containers with glass or quartz windows and MgO or Al_2O_3 light reflectors. 'Well' types if required. Manufacturers:—Ekco, Harshaw (UK agent:—Nuclear Enterprises), Hilger & Watts, Quartz et Silicie (UK agent:—Nash & Thompson), Tracerlab (UK agent:—Bruce Peebles)
CsI-Tl	Density 4·51 Refractive index 1·79 Photoelectron yield per MeV:—2000 (electrons), 2900 (protons), 1650 (alpha) (2) Light pulse rise and decay depends on dE/dx (4) Average scintillation pulse decay time (interpreted as exponential decay) 0·7 μs (electrons), 0·6 μs (8 MeV proton), 0·4 μs (5 MeV alpha) Gamma energy (keV) 20 33 34 50 100 200 500 1000 2000 5000 10000 Gamma absorption coeff. (cm^{-1}) 10·2 1·78 0·438 0·262 0·183 0·161 0·183 Typical applications: alpha particles and proton detectors and spectrometers, gamma dectectors and spectrometers.	Single crystal, thin or thick (up to 5 in. dia. × 4 in. reported to date) not hygroscopic. May be machined and mounted in normal atmosphere. Manufacturers:—Hilger & Watts, Harshaw (UK agent:—Nuclear Enterprises), Quartz et Silicie (UK agent:—Nash & Thompson)
LiI-Eu	Density 4·06 Photoelectron yield per MeV (5):—1500 (electrons), 2000 (protons), 1000 (5 MeV alpha) (2) No useful dependence reported on light decay and dE/dx Average decay time 1·4 μs Gamma Ray absorption very similar NaI/Tl Neutron absorption coefficients Neutron energy 0·025 eV 0·1 eV 1 eV 10 eV 100 eV 1 keV 10 keV 100 keV Li^{nat}.I-Eu (cm^{-1}) 1·31 0·66 0·21 0·75 0·037 Li^{6}I-Eu (cm^{-1}) 17·2 8·6 2·8 0·82 0·29 0·11 0·051 0·31 Typical applications: Slow neutron and gamma ray detectors Fast neutron detectors and spectrometers (cooled to 44°K) (7)	Single crystals, very hygroscopic. Almost always purchased mounted in sealed moisture proof containers for attachment to photomultiplier. Manufacturers:—Harshaw (using natural Li or 96% Li-6) (UK agent: Nuclear Enterprises)

TABLE 1 Phosphors—Continued

TYPE	PRINCIPAL PHYSICAL PROPERTIES	FORMS AVAILABLE, PROPRIETARY TITLES, SUPPLIERS.
ZnS-Ag	Luminescent powder. Small crystals 10–100 μ Density 4·09 Refractive index 2·36 Photoelectron yield per MeV:—4000 (alpha) Light pulse decay law $E^{-1\cdot2}$ (alpha particle excitation) Time for ½ total light to be emitted ~ 3 μs Optimum thickness for 5 MeV alpha particles 9 mg/cm² Maximum useful thickness 80 mg/cm² Typical applications: alpha particle detectors, soft beta particle detectors (using delayed coincidences (8)), neutron detectors in combination with hydrogenous or neutron active media (see below) (9) (10)	Bulk crystalline powder or mounted as thin layers on transparent backing. Levy West, Derby & Co., Nuclear Enterprises, Nash & Thompson. Alpha particle detectors (mounted on transparent backing with light proof alpha window on front). Nash & Thompson.
Anthracene	Organic crystals $C_6H_4(CH)_2C_6H_4$ Density 1·25 Integrated photoelectron yield per MeV:—1500 (1 MeV electrons) 450 (3 MeV protons) 120 (5 MeV) Light pulse decay of form A exp. $(-t/\tau)$ + low level $t^{-1\cdot25}$ decay (11) Exponential component decay time τ ~ 30 ns Fraction of integrated light in power law decay 20% (0·5 MeV electrons) 35% (1·5 MeV protons) 40% alpha (0·5 MeV alpha) (11) Variation of light output with direction of exciting particle ± 20% (12) Typical applications: beta ray spectroscopy, proton and fast neutron spectroscopy using decay time discrimination (13) (14)	Single crystals or crystalline blocks. Nash & Thompson, Harshaw.
Stilbene	Organic crystals C_6H_5 CH:CHC_6H_5 Density 1·16 Integrated photoelectron yield per MeV:—1200 (1 MeV electrons) 400 (3 MeV proton) 85 (5 MeV alpha) Light pulse form A exp. $(-t/\tau)$ + low level $t^{-1\cdot25}$ decay (11) Exponential component of decay 6 ns Fraction of integrated light in power law decay 40% (0·5 MeV electrons) 70% (1·5 MeV protons) 80% (5 MeV alpha) (11) Expected variation of light output with direction of exciting particle, as for anthracene. Typical applicatons: Fast coincidence counting, proton and fast neutron spectroscopy using decay time discrimination	Single crystals or crystalline blocks. Nash & Thompson, Harshaw.
Scintillating liquids A.	Typical mixtures (do not necessarily conform with proprietary articles) (a) 4g/l PPO or p-terphenyl + 0·1 g/l POPOP in toluene (15). Photoelectron yield per MeV:—900 (1 MeV electrons) (b) 10 g/l PBD in xylene or toluene (15). Photoelectron yield per MeV:—1060 (1 MeV electrons) (c) 4 g/l PPO in toluene (15). Photoelectron yield per MeV:—750 (1 MeV electrons) Density ~ 0·87 Refractive index 1·497 Fast component of decay 2–3 nanosec, slow component of decay 0·2 μsec Slow component only useful for proton/electron discrimination if dissolved oxygen is removed	1. Scintillation grade chemicals for mixing as required. Nuclear Enterprises, Nash & Thompson. 2. Prepared solute mixtures. Scintipac 1 & 3, Nash & Thompson. 3. Prepared bulk solutions. Scintol 1, 2 & 3, Nash & Thompson. NE 211 NE 212, Nuclear Enterprises. TTP3, 4 & 5, Panex. 4. Sealed into glass vessels with MgO or other reflectors. Nuclear Enterprises.
Scintillation Liquids B	Solutions into which water or metal organic compounds may be loaded Typical mixtures (not necessarily proprietary article) PBD (8 g/l) + POPOP (0·05 g/l) + Naphthalene (80 g/l) + xylene to which may be added methyl borate and other metal compounds, substances dissolving in methanol or butanol; water if mixed with 1·4 dioxane; PPO (5g/l) + α NPO (0·5 g/l) + naphthalene (80 g/l) in solvent of 5 parts xylene, 5 parts 1–4 dioxane + 3 parts ethanol (V/V) – (dissolves 7·7% water) (16) Approximate density 1 to 0·9 Approximate refractive index 1·5 Photoelectron yield per MeV:—700–900 (1 MeV electrons) 60–80 (5 MeV alpha) Fast component of decay 2–3 nanosec. Slow component for decay time discrimination ~ 0·2 μs Applications C^{14} and H_3 assay using aqueous solutions Gamma ray and neutron detectors when suitably loaded (17)	1. Scintillation grade chemicals. Nuclear Enterprises, Nash & Thompson 2. Prepared solute mixtures. (Scintipac 3), Nash & Thompson 3. Bulk solutions without loading. (NE 213) Nuclear Enterprises (Scintol 3). Nash & Thompson (TED/5), Panax 4. Bulk solution with loading. (NE 311, 5% W/W B) (NE 312, 6% W/W Cd) (NE 313, 1% W/W Gd) (NE 314, 5% W/W Pb) (NE 315, 1% W/W Sm) Nuclear Enterprises
Scintillation Liquids C	Monoisopropylbyphenyl scintillation solution Application: low volatility solvent, useful for filter paper techniques	(NE 215) Nuclear Enterprises
Scintillation gels	PPO (3 g/l) + Thixcin (organic castor oil derivative) (25 g/l) in toluene (18) Photoelectron yield about 800 (1 MeV electrons) Applications:—counting of particulate beta or alpha activity	(NE 210) Nuclear Enterprises
Plastic Scintillators A	Typical composition (not necessarily proprietary article) 36 g/l p-terphenyl + 1 g/l POPOP in Polyvinyltoluene (15) 2·5% p-terphenyl + 0·08% TPB + 0·01% zinc stearate in polystyrene (for large volumes) (19) Density ~ 1·06 Refractive index ~ 1·58 Photoelectrons yield per MeV:—750 (1 MeV electrons) 250 (3 MeV protons) 60 (5 MeV alpha) Main decay about 3·5 nanosec. Gamma energy keV 20 50 100 200 500 1000 2000 5000 10000 Gamma ray absorption coefficients. cm^{-1} 0·48 0·20 0·16 0·128 0·084 0·068 0·048 0·0255 0·015 Applications:—general, where relatively inexpensive and robust scintillating material is required for alpha, beta, gamma detection	Rod, blocks, discs thick sheet, filament, granules, etc., or cut to any shape as required—weights up to 1 ton. (NE 102) Nuclear Enterprises (Naton 11, Naton 136) Nash & Thompson Tube or vessel for flow counters. (NE 80 NE 802). Thin sheets attached to transparent backing (NE 810) for alpha detection.
Plastic Scintillators B	For discrimination between electron and proton excitation 3·5 gm/1 p-terphenyl + 0·5 gm/1 POPOP in polyvinyltoluene + 10% monoisopropylbiphenyl (20) Density ~ 1 Photoelectron yield per MeV:—1200 (electrons)	(Plastic 77=NE 150) Nuclear Enterprises
Plastic Scintillators C	Air equivalent phosphor Suspension of ZnS in plastic phosphor to have mean d.c. light output proportional to X-ray dose in air (21) Application:—gamma and X-ray dose measurement, intensifying screens for low level photographic dosimetry	Nash & Thompson
ZnS-Ag based neutron detectors	Dispersion of ZnS in Boron polyester or mixtures (22) of ZnS in B_2O_3 glass (9) Neutron detection efficiency (limited by transparency of ZnS) 15–25% for thermal neutrons, depending on level of gamma rejection required.	Discs, ready for use available in natural Boron or B^{10}. (NE 400), (NE 401) Nuclear Enterprises. (Slow Neutron Detectors) Nash & Thompson

TABLE 1 Phosphors—continued

TYPE	PRINCIPAL PHYSICAL PROPERTIES	FORMS AVAILABLE PROPRIETARY TITLES AND SUPPLIERS
ZnS-Ag based fast neutron detectors	Dispersion of ZnS in hydrogenous plastic (10) (Hornyak buttons) with various modifications to improve light collection (Emmerich detectors). Count rate proportional to energy transported by the fast neutron flux. Efficiency for 1 MeV neutrons (about 1%) is reduced if higher level of gamma rejection required.	(NE 450, 451) Nuclear Enterprises (FN1, FN2) Nash & Thompson.
Scintillating glasses	Cerium activated lithium magnesium silicate (23) Typical composition 0·065 Li_2O, 0·26 MgO, 0·05 Al_2O_3, 0·50 SiO_2 (Molar proportions) (24) Density 2·7 Refractive index 1·57 [Emission maximum 3950 Angström] Decay time 0·14 μs (alpha) Photoelectron yield per MeV:—450 (1 MeV electrons) 150 (5 MeV apha) Application:—gamma and slow neutron detection.	Moulded blocks, cut and polished. Manufactured as GS1 by Levy West Laboratories Ltd. Also obtainable from Nash & Thompson.

TABLE 2 Photomultipliers for scintillation counting

Photomultipliers most suited for scintillation counters have low-noise photo-emissive cathodes deposited on the interior surface of the end window of the envelope. Multipliers described here are all of this type except for the 27 M1 and 27 M3. The various photocathode spectral responses of interest have been codified as follows:—

S1—Cs-Ag-O	maximum sensitivity in the infra-red
S4, S8, S9—Cs_3Sb(O)	manufacturing variants of Cs_3Sb(O)
S5—Cs_3Sb(O)	S4 type in UV transmitting glass
S10—Bi-Ag-O-Cs	low-noise, high-red sensitivity
S11—Cs_3Sb(O)	normal high efficiency low-noise photocathode in glass
S13—Cs_3Sb(O)	in fused silica for UV sensitivity
S17—Cs_3Sb(O)	on aluminium reflector (high sensitivity)
S20—(Cs K Na)Sb —(Na K) Sb	high efficiency, high-red sensitivity suitable for high temperature operation (~150°C)

Only manufacturers' published minimum specifications are quoted, where these are available. Where average or expected values only have been published these are indicated by (AV). No indication is given here of the voltage distribution at which the specified gain is obtained. The cathode sensitivity is normally measured in micro-amps per lumen of tungsten light at a colour temperature of 2848°K. It may be noted that a 70μA/l for an S11 cathode corresponds to a quantum sensitivity of about 20% in the peak of the spectral response (about 4400Å). For S20 (tri-alkali cathodes) 150 μA/lumen corresponds to a 22% quantum efficiency at 4200Å.

TYPE NO. GLASS BULB	SILICA WINDOW EQUIVALENT	APPROX. BULB DIA.	MULTIPLYING STAGES NO.	MULTIPLYING STAGES TYPE	PHOTOCATHODE RESPONSE	PHOTOSENSITIVITY MIN. μA/lm	PHOTOSENSITIVITY AV. OR TYPICAL μA/lm	MAX. VOLTS TO OBTAIN SPECIFIED SENSITIVITY	ANODE DARK CURRENT OR EQUIVALENT INPUT AT SENSITIVITY SPECIFIED	BASE	MAIN APPLICATION
Allen B. Dumont Ltd. (USA)											
6291		1½ in.	10	box	S11	40	60	4A/lm @ 105V/stage	0·05μA @ 105V/stage	B12A	
6292	K1306	2 in.	10	box	S11 (S13)	40	60	4A/lm @ 105V/stage	0·05μA @ 105V/stage	B14A	
6363	K1758	3 in.	10	box	S11 (S13)	40	60	4A/lm @ 105V/stage	0·05μA @ 105V/stage	B14A	
6364		5¼ in.	10	box	S11	40	60	4A/lm @ 105V/stage	0·05μA @ 105V/stage	B14A	
K1386		20 in.	12	box	S11		40	32A/lm @ 105V/stage (AV)	0·5 μA @ 105V/stage	special 25 pin	
Most Dumont tubes are available with either AgMg or CsSb dynodes under different type numbers to a slightly different gain specification, e.g.: 6292 (AgMg) = 7064 (CsSb), 6291 (AgMg) = 7065 (CsSb), 6363 (AgMg) = K1390 (CsSb), 6364 (AgMg) = K1391 (CsSb)											
Dario (Mullards Ltd.) (UK) Philips Ltd. (Continent)											
50AVP	51UVP	38mm (42)	11	linear focus	S11 (S13)	—	50	60A/lm @ 1800V	0·05μA @ 60A/lm	B12A	
52AVP		25mm	10	box	S11	—	30	13A/lm @ 1800V	0·1μA @ 15A/lm	special 13 pin	
53AVP	53UVP	55mm	11	linear focus	S11 (S13)	—	50	60A/lm @ 1800V	0·05μA @ 60A/lm	B14A	
54AVP		130mm	11	linear focus	S11	—	50	100A/lm @ 1800V	0·5μA @ 250A/lm	B14A	
55AVP		55mm	15	linear focus	S11	—	50	500A/lm @ 2000V	5μA @ 500A/lm	duodecal 20 pin	
56AVP		55mm	14	linear focus	S11		50	$\geq 10^8$ gain @ 2000V	$<5\mu$A @ 10^8 gain	duodecal 20 pin	high speed, high gain multiplier 2ns transit time spread
57AVP		235mm	11		S11		50	60A/lm @ 1800V	1μA @ 60A/lm	special base	
58AVP		130mm									large area very fast response
150AVP		38mm	10	linear focus	S11		50	60A/lm @ 1800V	0·05μA @ 60A/lm	B12A	
DARIO photomultipliers made by Laboratoires d'Electronique et de Physique Appliquée are marketed in the UK by Mullard Ltd. and by Research and Control Instruments Ltd. (agent for Philips)											
EMI Electronics Ltd.											
6097B		2 in.	11	venetian blind	S11	30	50	200A/lm @ 1960V	0·1μA @ 200A/lm	B15B	general purpose photomultiplier
6097F		2 in.	11	venetian blind	S11	40	60	50A/lm @ 1960V	0·1μA @ 50A/lm	B15B	high cathode sensitivity 6097
6097		2 in.	11	venetian blind	CsSb	20	30	200A/lm @ 1960V	0·1μA @ 200A/lm	B15B	low noise version 6097
9584B S.X.		2 in.	11	venetian blind	S11	30	50	200A/lm @ 1800V	0·1μA @ 200A/lm	diheptal (B14A)	overcapped version of 6097
9536 (S)	9522B (S)	2 in.	10	venetian blind	S11 (S13)	30	50	50A/lm @ 1700V	0·05μA @ 50A/lm	diheptal (B14A)	10 stage overcapped tube similar 6097
9514B (S)	6255B (S)	2 in.	13	venetian blind	S11 (S13)	30	50	2000A/lm @ 2100V	1·0μA @ 2000A/lm	B15B	Available as 9502 with 1cm cathode
9558		2 in.	11	venetian blind	S20		100	200A/lm @ 1800V(AV)	0·004μA @ 200A/lm(AV)	special 20 pin	tri-alkali version 6097
9593B		2 in.	14	linear focus	S11		45	2000A/lm @ 2000V(AV)	1μA @ 2000A/lm(AV)	special 20 pin	high gain <5ns transit time spread
9524B (S)	9526B (S)	1½ in.	11	box	S11 (S13)	30	40	200A/lm @ 1400V	0·05μA @ 200A/lm	B14B	
9530B	(IR)	7½ in.	11	venetian blind	S11	30	50	100A/lm @ 1800V	0·2μA @ 100A/lm	B15B	
9579B	(U.I.R.)	5 in.	10	venetian blind	S11	30	50	50A/lm @ 1800V	0·1μA @ 50A/lm	diheptal (B14A)	

TABLE 2 Photomultipliers—continued

TYPE NO. GLASS BULB	SILICA WINDOW EQUIV-ALENT	APPROX. BULB DIA.	MULTIPLYING STAGES NO.	MULTIPLYING STAGES TYPE	PHOTO-CATHODE RESPONSE	PHOTOSENSITIVITY MIN. μA/lm	PHOTOSENSITIVITY AV. OR TYPICAL μA/lm	MAX. VOLTS TO OBTAIN SPECIFIED SENSITIVITY	ANODE DARK CURRENT OR EQUIVALENT INPUT AT SENSITIVITY SPECIFIED	BASE	MAIN APPLICATION
EMI (*contd*)											
9531B		3½ in.	11	venetian blind	S11	30	50	200A/lm @ 2060V	0·5μA @ 200A/lm	B15B	
9545		12 in.	11	venetian blind	S11	30	50	200A/lm @ 2200V	4μA @ 200A/lm	B15B	
9578B	(S, X, U, IR)	3 in.	10	venetian blind	S11 (S20)	30	50	50A/lm @ 1700V	0·1μA @ 50A/lm	diheptal (B14A)	also available with tri-alkali cathode
9583	(U, IR)	5 in.	11	venetian blind	S11	30	50	100A/lm @ 1800V	0·2μA @ 100A/lm	diheptal (B14A)	overcapped version of 9530

The last letter of the type number of photomultipliers made by EMI indicates small variations in type, special processing, or selection after manufacture to meet a particular specification as follows:

A. Selected to meet customer's specification
B. Good photosensitivity and gain, low dark current
C. Tubes to somewhat lower specification than B tubes
S. Specially processed to give extremely low dark current, particularly suited for C^{14} or H^3 assay
F. High photosensitivity, moderate gain and dark current
G. Selected to deliver large current pulses at higher than normal working voltage
E. Selected for high gain at low working voltage
X. With NESA conducting coating on the window to allow operation at low temperature (~77°K)
U. With B15B base
IR. Infra-red version with S1 cathode

The figures quoted are, in general, for B-type tubes.

CBS Hytron (USA)											
CL1002	(CL1008)	2 in.	10	linear focus	S11 (S13)	50	60	5A/lm @ 1250V	2×10^{-9}lm @ 20A/lm	diheptal (B14A)	
CL1003		3 in.	10	linear focus	S11	50	60	5A/lm @ 1250V	2×10^{-9}lm @ 20A/lm	diheptal (B14A)	
CL1004		2 in.	14	linear focus	S11	NA		NA			fast, high current tube
Fernseh (GmbH) (Germany) (UK agents: Livingston Laboratories Ltd.)											
FS9A		1½ in.	9	focused	S11	40	60	24A/lm @ 1000V	3×10^{-9}lm @ 24A/lm		
FS12A47		2 in.	12	focused	S11	50		6×10^5 gain @ 1300V	10^{-9}lm equivalent		
FS10A70		3 in.	10	focused	S11	50		10^5 gain @ 1100V	10^{-9}lm equivalent		
FS12A70		3 in.	12	focused	S11	50		6×10^5 @ 1500V	10^{-9}lm equivalent		
		Versions of the FS9A phototube are available as FS9F series with selected photocathode sensitivities varying between 35—105μA/lm and with different gain specifications. FS9A is chosen as typical.									
Mazda											
27M1		side cathode	9		S4	20		10^6 gain @ 100V/stage (AV)	0·25μA @ 10^6 gain		
27M3		side cathode	9		S5	10		10^6 gain @ 100V/stage (AV)	0·25μA @ 10^6 gain		Small side windows used in alpha probes
Radio Corporation of America											
5819		2 in.	10	circular focus	S11	40	50	10A/lm @ 1000V	2×10^{-9}lm @ 20A/lm	diheptal (B14A)	curved cathode general purpose
6199		1½ in.	10	circular focus	S11	30	45	10A/lm @ 1000V	$2{\cdot}5\times10^{-9}$lm @ 20A/lm	diheptal (B12A)	
6342A		2 in.	10	circular focus	S11	50	80	4A/lm @ 1250V	2×10^{-9}lm @ 20A/lm	diheptal (B14A)	fast response moderate gain
6655A		2 in.	10	circular focus	S11	40	55	10A/lm @ 1000V	2×10^{-9}lm @ 20A/lm	diheptal (B14A)	fast response moderate gain
6810A		2 in.	14	linear focus	S11	50	70	120A/lm @ 2000V	2×10^{-9}lm @ 2000A/lm	bidecal	fast response
7264		2 in.	14	linear focus	S11	50	70	120A/m @ 2000V	2×10^{-9}lm @ 2000A/lm	bidecal	very fast response
7265		2 in.	14	linear focus	S20	100	150	165A/lm @ 2400V	8×10^{-10}lm @ 1000A/lm	bidecal	tri-alkali fast tube
7326		2 in.	10	linear focus	S20	120	150	5A/lm @ 1800V	$1{\cdot}4\times10^{-9}$lm @ 20A/lm	diheptal	tri-alkali
7046		5 in.	14	linear focus	extended S11	40	60	40A/lm @ 2800V	$1{\cdot}2\times10^{-9}$lm @ 500A/lm	'Thirty-fivar 21 pin'	large area fast tube
C7260		2 in.	10	linear focus	S11			NA			fast, high gain multiplier
Schlumberger Well Surveying Corp.											
			14	venetian blind	NA			200A/lm @ 4000V			rugged tube for high temperature operation
20th Century Electronics Ltd.											
VMP11/ 44/A		2 in.	11	venetian blind	S11	40		200A/lm @ 1700V	0·1μA @ 200A/lm	B15B	
VMP11/ 44B	VMQ/ 11/44	2 in.	11	venetian blind	S11 (S13)	30		200A/lm @ 1700V	0·1μA @ 200A/lm	B15B	
VMP11/ 44C		2 in.	11	venetian blind	S11	20		10A/lm @ 1920V	0·05μA @ 200A/lm	B15B	
VMP11/ 111		5 in.	11	venetian blind	S11	30		200A/lm @ 1900V	0·15μA @ 200A/lm	B15B	
VMP11/ 170		5 in.	11	venetian blind	S11	30		200A/lm @ 2000V	1·0μA @ 200A/lm	B15B	
BMS11/ 23B	BMQ/ 11/23	1⅛ in.	11	box	S11 (S13)	30		200A/lm @ 1500V	0·1μA @ 200A/lm	B14B	
BMS10/ 14B	BMQ/ 10/14	⅞ in.	11	box	S11 (S13)	30		150A/lm @ 1700V	0·1μA @ 150A/lm	B12J	
		Three grades A, B, C are normally offered by 20th Century based on selection.									
USSR											
FEU19		1⅞ in.	13	linear focus	S11	10		100A/lm @ 1900V	0·6μA @ 10A/lm		
FEU24		3½ in.	13	linear focus	S11	25		10A/lm @ 1600V	0·3μA @ 10A/lm		
FEU25		1⅝ in.	9	linear focus	S11	20		1A/lm @ 1250V	0·05μA @ 1A/lm		
FEU33		1⅛ in.	13	linear focus	S11	30		100A/lm @ 2100V	1μA @ 100A/lm		fast, high current tube
		Data from 'Handbook on Dosimetric Radiometric and Electronic Physical Instruments, Counters, Scintillators and Photomultipliers'.									

TABLE 3 Scintillation detector assemblies

The photomultiplier listed is that specified in the manufacturer's current literature, but it could be subject to change as other types can be used sometimes in the same equipment, with or without modifications. Where an attachment is advertised as available, it is indicated in the table.

The descriptions are necessarily brief and manufacturers should be approached directly for further details if these are required.

MANUFACTURER	DESIGNATION	BRIEF DESCRIPTION	PHOTOMULTIPLIER Type (where specified)
Airmec Ltd	255	alpha survey probe ZnS-Ag screen 5 in² area sample changer available	6097 or VMP/11/44
Burndept Ltd	BN 101	directional scintillation counter collimators available	
	BN 120	universal scintillation counter collimators available	6097 or VMP/11/44
	BN 111	radiation monitor embodies ZnS-Ag alpha detector	VMP/11/44
EKCO Electronics Ltd	N618	lightweight medical scintillation counter	11 stage 23 mm cathode
	N651	collimator assembly for N.618	
	N559B	scintillation counter for use as gamma spectrometer	11 stage 44 mm cathode
	N559B	scintillation counter single coaxial connection lead castles available for 559 series	11 stage 44 mm cathode
	N559D	N559C fitted with annular steel shield and collimator	11 stage 44 mm cathode
	N559E	scintillation counter with 200 ohm output cathode follower	11 stage 44 mm cathode
	N559F	scintillation counter single coaxial connection lead castles available for 559 series	11 stage 44 mm cathode
	N664	universal scintillation counter lead castle assembly for annular samples or well crystals shutter fitted for internal beta assay e.g. C^{14} or H^3 in solution	
	N676	scintillation unit for gamma spectroscopy	6097F
	N674	scintillation counter alpha or gamma head may be fitted	11 stage 23 mm cathode
EMI Electronics Ltd		alpha hand and clothing monitors survey meters	E.M.I.
E.R.D. Engineering Co Ltd	E.R.D.	scintillation castle, liquid sample scintillation counter, universal scintillation counter (all with lead shields)	6097
Ericsson Telephones Ltd	214A	universal scintillation counter head, available with alpha, beta and gamma phosphors collimators and lead castle available	20th C.BMS 11/23
General Radiological Ltd	NE060	alpha floor probe	6097 or VMP/11/44
Hilger & Watts Ltd		3 in. × 3 in. Na-Tl crystals internally canned with phototube fitted into phototube mounting assembly	EMI 9531
Isotope Developments Ltd	NA	two multiplier coincidence assembly for H_3 counting	
	653	scintillation counter head	
	661	counter assembly using photomultiplier collimator attachments available	9524
	663A	unshielded counter assembly for general purpose beta or gamma survey	6097B
	663B	unshielded counter assembly for low energy beta counting	9514S
	772	lead castles for 663A and 663B	
	723	windowless scintillation counter with 663 and phosphor	
	700	diagnostic scintiliation counter collimators available	
	1413A	portable scintillation rate meter	
Labgear Ltd	D4133	directional scintillation counter collimators available	EMI 9524
	D4132	gamma sensitive end-window counter for industrial applications	6097 or VMP/11/44
	D4105	annular sample or well crystal for gamma assay	6097 or VMP/11/44
Mervyn Instruments	1483A	large area alpha assay equipment	6097
	1257	alpha monitoring probe	
	1320 + 1355B	alpha assay equipment	6097
Nuclear Enterprises (GB) Ltd	NE5501	lead shielded scintillation head	EMI 1 in. or 2 in. dia.
	NE5503	shielded scintillation head for C^{14} or H^3 analysis incorporates single low noise multiplier, light shutter and cooling coils	EMI 9524S
	NE5520	scintillation head unit for X-rays	EMI 1in.
	NE8101	human body counter installation, incorporating three 15 in. dia. × 8 in. plastic scintillators (variations possible)	3 off 12 in. EMI or 9 off 5 in. EMI
	NE8102	human body counter installation, incorporating four 4 in. dia. × 2 in. Nal-Tl phosphors	4 off 5 in. EMI
	NE8103	human body counter installation, incorporating one 9 in. dia. × 4 in. Nal-Tl phosphors	1 off 12in. or 3 off 3in. EMI
	NE8104	human body counter installation, combination of 8101 and 8102	
	NE8105	low level counting facility for large volume samples (60 lb)	
	NA	scintillation counter for pulse shape discrimination	
	Scintillometer Mk. XII	for airborne or carborne survey embodies 4 in. dia. × 4 in. Nal-Tl crystal + 4 channel analyser for indicating K, U, Th, and total count on 4-pen recorder.	
Panax Equipment Ltd (Export Division operated by Nuclear Research Applications Ltd)	USC-A	basic end window counter lead castle available planchets	6097
	USC-B	well counter for use with NaI or plastic lead castle available for gamma assay	6097
	USC-C	annular sample counter lead castle available for gamma assay	6097
	USC-D	directional scintillation counter collimators available for gamma survey	6097
	SC-LP	single photomultiplier assembly in lead castle with shutter assembly; and cooling facilities for use in low energy beta assay with liquid phosphors	6097S
	SC-G & SC-BA	invertible single photomultiplier assembly in lead castle for use with liquid samples (SC-G) or planchets (SC-BA) gamma or beta assay (many standardized components are used with above and conversion from one type to another is often possible)	6097
Philips (agents: Research & Control Instruments Ltd)	PW4111	general purpose survey probe using 1 in. dia. × ½ in. Nal-Tl crystal other crystals, collimators, lead castle and sample changer assemblies available	50AUP
	PW4119	general purpose survey probe using 1½ in. dia. × 2 in. Nal-Tl crystal lead shields and sample changers available	53AVP
	L313	alpha probe for contamination monitoring ZnS-Ag phosphor 10 × 10 cm aluminized terylene foil light seal	
Plessey Nucleonics Ltd	PNI 1080	scintillation detector for x-ray detection of Pu-239 etc.	
	P-20CM	basic scintillation detector for which a variety of detecting phosphors, collimators, lead shields, etc. are available	RCA 6655
Tracerlab (agents: Bruce Peebles & Co Ltd)	L-SC10	liquid scintillation counting system for C^{14} or H^3 analysis	
	SC57	well crystal counter	RCA 6655

The IAEA examines reactor costs

The first of a series of reports compares the economics of proposed stations on a uniform cost basis

WHAT IS described as an initial step towards wider investigations into the economics and technology of nuclear power has been undertaken by the International Atomic Energy Agency. A first report 'The Development of Nuclear Power',* indicates the direction in which nuclear power costs can be expected to fall. It is to be followed by others which will take into account the introduction of nuclear power within a mixed thermal hydroelectric system as well as the full economic implications of its development within a given country. A series of studies on methods of nuclear power costing has also been initiated and a panel of experts is to meet in November.

The first report, which includes the table below, says that important cost reductions can be expected from technical advances but more significant will be possible reductions in fuel cycle costs. These will result from lower fabrication and reprocessing charges, higher burn-ups and a fall in uranium prices. Basically, this study has been designed to facilitate 'a preliminary evaluation by less-developed countries, of power plants using nuclear instead of conventional fuels.' However, it does not deal with cost comparisons between nuclear and hydroelectric power. Cost data and figures presented refer essentially to projected nuclear costs (plants to be commissioned about 1965) and not to costs of reactors now in operation or under construction.

Data are presented as a function of plant output for: (a) the initial investment cost per net kilowatt of capacity; (b) fuel replacement cost as cost per kilowatt hour and (c) annual operating and maintenance cost per net kilowatt of capacity. They are primarily concerned with the larger sized power reactors as the report says that technical data for small and medium reactors are at present insufficient to permit cost estimates of comparable reliability.

Among the points are:

(a) Estimates for large nuclear plants to be built in the next five years indicate that the cost per kWe installed will exceed that of similar-sized conventional stations by a factor of 1·5 or more. Potential reductions may bring this ratio down to about 1·3.

(b) Every component of fuel costs offers room for substantial reductions in the near future. Reductions of up to 30% in total fuel costs in the next five to 10 years may be expected even if a possible decrease in credit for plutonium is taken into account.

(c) There is still insufficient information on operating and maintenance costs of nuclear stations used solely for electricity production. However, reductions in operating staff, increased automation and lower repair bills are likely. This item though, represents less than 10% of the total costs so a swing of 20% saving would imply only a 2% overall saving.

(d) Sizeable savings can be expected from standardization and improvement of reactor components such as pumps, valves and heat exchangers.

* *The Development of Nuclear Power (Review of nuclear power costs) IAEA report GC(IV)/123.*

Costs of power stations planned for 1965[a]

ITEM OF COST	PWR				BWR				GCR			HWR				CONVENTIONAL	
	75 MWe		300 MWe		75 MWe		300 MWe		300 MWe	132 MWe		200 MWe[c]		235 MWe	
	$/kW	%	$/kW	%	$/kW	%	$/kW	%	%	$/kW	%	$/kW	%	$/kW	%
Site preparation and improvements	17	4	5	2	19	4	5	2				7	2		
Containment and civil works	44	10	12	5	52	11	29	11	25	77	20	26	8	32	18
Other structures and civil works	26	6	9	4	23	5	11	4				36	11		
Reactor equipment	61	14	27	11	75	16	29	11	21	39[b]	10[b]	54[b]	16[b]		
Fuel handling	13	3	5	2	14	3	5	2	1	11	3	8	3		
Waste disposal	5	1	2	1	5	1	3	1	1	15	4	4	1	Boiler equipment.	
Instrumentation	17	4	5	2	23	5	8	3	1	8	2	22	7		
Primary coolant equipment	65	15	41	17	52	11	29	11	12	54	14	17	5	63	36
Water supply and treatment	4	1	5	2	9	2	5	2	4	8	2	8	2		
Steam generation equipment	48	11	29	12	52	11	34	13	14	39	10	15	5		
Turbo-generator and auxiliaries	61	14	55	23	71	15	58	22	19	66	17	42	13	63	36
Condenser and water system	17	4	15	6	19	4	13	6	1	19	5	15	4		
Auxiliary and miscellaneous power plant equipment to high voltage line	26	6	15	6	23	5	16	5	1	23	6	29	9	6	3
Interest during construction	31	7	18	7	33	7	18	7	27	27	7	46	14	12	7
GRAND TOTAL	435	100	242	100	470	100	263	100	100	386[b]	100[b]	328[b]	100[b]	176	100

[a] *Figures given for nuclear plants are provisional, relating only to planned reactors. All indirect costs have been proportionately shared between the various items of cost shown in this Table.*

[b] *The cost of the D_2O moderator is not included in this figure.*

[c] *The information for this station was received at a late date. In the time available it has not been possible to reconcile some of the figures for the station with those for other stations, particularly those relating to heat transfer and steam generating equipment.*

Following the article dealing with magnox reactors in September, some of the interesting possibilities for other systems are examined

Steam cycles for power reactors - 2

by W. J. THOMAS, B.Sc.(Eng.), A.M.I.Mech.E., A.M.I.E.E., Mem.ASME., and R. A. LORGE, B.Sc.(Eng.),A.M.I.Mech.E., A.M.I.Mar.E., Kennedy & Donkin

THE PREVIOUS ARTICLE outlined the improvements in steam turbine cycles leading to higher efficiencies in conventional stations. It went on to describe how steam turbine cycles have been modified for nuclear stations where the reactor coolant temperatures are low in comparison with furnace gas temperatures in coal or oil-fired stations, giving rise to poorer steam conditions.

It is at this stage advisable to summarize the problems connected with cycle selection. The reactor coolant outlet temperature is decisive in determining not only the maximum steam temperature but also the optimum steam pressures in the H.P. and L.P. circuits. For the highest efficiency, it is necessary to supply as much heat as possible to the steam at the highest possible pressure and temperature. Pressures must not be set too high, however, if excess terminal steam wetness is to be avoided unless superheat, reheat, or steam drying devices are introduced.

Present gas-cooled reactor cycles

The dual pressure cycle has been used due to the relatively low gas coolant temperatures available to date; it shows a worthwhile efficiency increase for the extra capital cost involved. Regenerative feed heating, which was not installed at Calder Hall, is now being re-introduced in nuclear station cycles and once more shows an efficiency gain.

It is of interest here to examine the mechanism of feed heating more closely so as to see its future possibilities. In conventional stations, working at high steam pressures, the addition of feed heating invariably improves the cycle efficiency. On the other hand, feed heating in nuclear stations working at relatively low pressures would actually reduce the L.P. pressure (*1*). Below a certain reactor coolant inlet temperature, this would have a more important effect than feed heating on efficiency so that an efficiency reduction may be expected. Conversely, feed heating may provide a mechanism for lowering steam pressures to a practicable value where terminal wetness is a limiting factor and reheat is not feasible. With rising reactor coolant temperatures (see p. 75 ref. (*2*)) this will provide a useful tool in shaping future steam cycles.

Another means of adjusting the steam pressure, with its consequence on feed heating, lies in the arrangement of the heating surfaces in the steam raising unit. For example, the L.P. superheater may follow the H.P. superheater and the H.P. evaporator (Calder Hall), or the H.P. superheater only (Hunterston), or both H.P. and L.P. superheaters may be at the same level. The other heating surfaces, e.g. evaporators and economizers, may similarly be arranged in various ways so that a considerable number of variables exist, each with its effect on the other and on the pressure, temperature, flow and efficiency of the complete cycle.

Some superheating of the L.P. and H.P. steam has been adopted from the start in all the UK gas-cooled stations, thereby increasing the efficiency and, by moving the turbine expansion as a whole to a higher entropy level, avoiding excessive terminal steam wetness. As operating steam pressures are being raised through increased coolant temperatures (*2*), the exhaust steam wetness is likely to become excessive unless the amount of superheat is also increased or reheat is introduced.

On the other hand, progress has been made in steam drying methods (*3*) during expansion, particularly in the turbines associated with American pressurized and boiling water reactors. Various means are available, either singly or together, such as internal drain bands, grooved turbine blades, cyclone separators, surface steam driers, and re-evaporators. Some of these methods entail a pressure loss, in addition to increased capital cost, but it would be quite possible to use such equipment if only a limited amount of super- or reheat is available.

The type of expansion which can then be obtained is shown on the Mollier diagram of Fig. 1 (*4*). This diagram was drawn for the turbine of the Dresden BWR which is fitted with moisture-extracting grooved turbine blades in the I.P. and L.P. stages and a moisture separator is installed in the cross-over piping between I.P. and L.P. cylinders. No drying takes place in the eight H.P. stages but the steam leaving the H.P. turbine mixes with dry steam on entering the I.P. cylinder and so the dryness of the mixture is raised. The dotted line, by comparison, shows a normal expansion with a final moisture content of 24%, which would be quite unacceptable.

Reheat of the H.P. steam has now been introduced for Dungeness, briefly described in the last article, and also for Tokai-Mura (*5*). The overall efficiencies anticipated for these stations are of interest, the values being 32·9% for Dungeness and 27·7% for Tokai-Mura. Unfortunately, not sufficient information has been released yet to account fully for the difference of 5·2% between these figures and the theoretical Rankine efficiency is only about 2½% better for Dungeness. It is, however, interesting to note this effect which the slightly better steam conditions of the Dungeness station have on the Rankine efficiency.

The thermodynamic cycle for Tokai-Mura is shown in Fig. 2*a*. But it should be noted that whereas the diagram is for one unit mass of working fluid at each point, the flows through the H.P. and L.P. circuits are in fact very

different. The amount of reheat is only approximately 6% of the total heat supplied. If this is to be increased in future cycles without increasing the circulator power appreciably, a layout different to that of the stations to date may become necessary in order to avoid excessively long pipe runs between turbine and reheater, causing a system pressure loss.

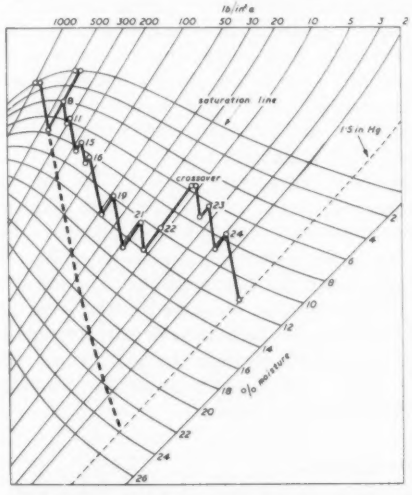
An interesting proposal for achieving a more compact station layout—though not in connexion with reheat—is the integral nuclear steam generator which, although patented about five years ago, has quite recently been brought to mind again by W. R. Wootton (*6*). This comprises one main pressure vessel housing both the reactor core and, below it, or alternatively above it, the steam raising unit. A biological concrete shield is proposed to separate the two components within the shell, with hooded ducts and stepped ports for the passage of the coolant gas through the concrete. The gas circulators would again be quite suitable for variable speed steam turbine drive.

Regenerative feed heating, which is now fully established for nuclear steam cycles, including the Tokai-Mura design, always presents some difficulty in its representation on a temperature-entropy diagram. This type of diagram, being based on unit mass of working fluid, cannot adequately show feed heating which depends on withdrawing a certain mass of fluid during the expansion. If this is indicated by a step in the expansion, as in Fig. 2*b*, the final quality of the steam is mis-represented. Nevertheless, it then shows clearly how the 'heat supplied' area is reduced, thus approaching the ideal Carnot cycle. Both methods are, therefore, somewhat misleading, which should be borne in mind when considering these diagrams.

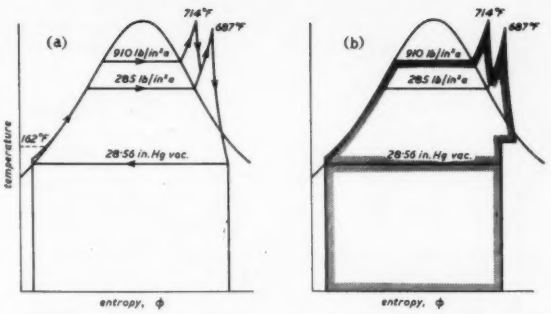
Present water moderated reactor cycles

The water moderated reactors at the present time produce either saturated steam or slightly superheated steam at a lower pressure in secondary circuits. With the PWR the secondary circuit and heat exchangers are necessary in order to prevent bulk boiling in the core. Apart from the cost of the heat exchange equipment itself, a pressure and temperature loss is inherent in such a system with a consequent loss of power and efficiency.

This problem is overcome in the type of BWR where



Expansion line shows the steam state in various turbine stages at the Dresden BWR station (Fig. 1) (*4*)



Alternative methods of representing Tokai-Mura steam cycles (Fig. 2)

the steam produced in the reactor core is used directly in the turbine. The temperature attainable depends on the fuel and the allowable pressure, with no theoretical limitations on the latter. It can be seen, therefore, that the BWR represents a potentially more efficient system.

Various systems exist—an example is the German Kahl/Main reactor—where a secondary circuit has been deliberately introduced for safety and maintenance reasons, whilst at Dresden a dual cycle incorporating both a primary and a secondary loop has been installed. The simplified flow diagram of the Dresden system is reproduced in Fig. 3.

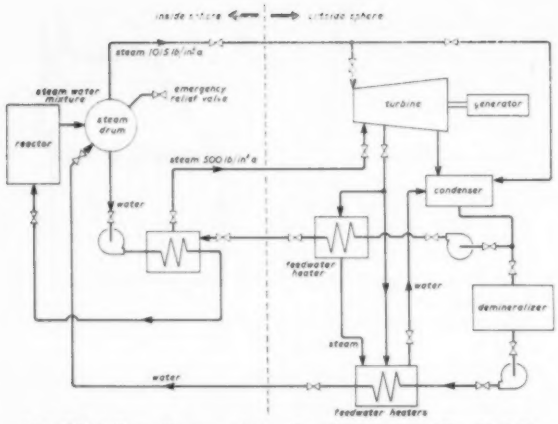
The reasons for adopting such a dual system are firstly that the higher coolant density of the water entering the reactor causes a larger reactor heat output, and secondly that on increasing load increased steam bubble formation in the primary circuit would reduce reactivity. This adverse characteristic is offset if the amount of heat devoted to bubble formation is reduced by the introduction of the secondary circuit. A disadvantage of the secondary circuit is its resultant lower steam pressure, a similarity with the PWR.

External superheat and reheat

Before continuing, it is important to point out that nuclear technology is still relatively in its infancy and that only one design of nuclear power station is actually in operation in this country to date. For this reason, it has been necessary to avoid any complication which might at this stage jeopardize the reliability of the station. As designers and operators gain experience, additional plant for obtaining higher efficiencies may be more readily acceptable.

These remarks apply especially to methods of providing additional superheat and possibly reheat externally to the present type of gas-cooled reactor cycles, and in particular to the present provision of superheat for the current pressurized and boiling water reactor cycles. The organic moderated reactor, still at an early stage of development, is in this aspect similar to the PWR and need not be discussed separately.

A number of proposals for externally fired super- and reheaters for these types of reactors have been put forward in recent years, all of them showing substantial savings in operating costs (*7*). As far back as December 1955, Kay and Hutchinson (*8*) calculated that in a typical 500 MWt system such a superheater, by increasing the heat supply by one third, can increase the initial power output by 50% with a thermal efficiency of 45%. This would increase the overall plant efficiency from 27·8% to 32·3% with a capital expenditure of only two thirds of that neces-



Simplified flow diagram of the Dresden system (Fig. 3) (*4*)

sary to provide this extra output by a conventional plant.

The Indian Point station for Consolidated Edison Company of New York Inc., is equipped with an oil-fired superheater and generating costs are expected to be 1·32 cents per net kWh. Without superheating, this figure has been estimated as 1·75 cents per net kWh (*9*). In this case, the output has been increased by approximately 70%, the total first cost by 17%, and the resultant saving in plant cost per kW is calculated at approximately 30%.

A combination of reheat with a triple-pressure steam cycle has been put forward by H. Benzler (*10*) and another cycle, utilizing both gas turbine and steam turbine driven alternators with a separately fired super- and reheater, was proposed by Hans Hiedl (*11*).

Against these proposals must be set the disadvantages of making the station dependent on two types of fuel, which are not alternatives, and the bulk supply of the fossil fuel would probably affect the siting of the station. Also, the slower thermal characteristics of a coal or oil fired furnace would present problems in matching and operation, particularly during start-up and shut-down. The general reluctance of accepting such 'hybrid' stations at this stage has already been mentioned, particularly with considerable progress on higher fuel temperatures in view.

Thought has also been given to heat storage (*12*) during off-peak hours so that the reactor can be kept working at full load and its heat utilized for either feed pre-heating or steam storage. Although such a system may show worthwhile savings under certain circumstances by improving the station load factor, this method is unlikely to be adopted in this country. Storage of low-grade heat, to which must be added high-grade heat before it can produce power efficiently, would not compare favourably with other systems. Pumped storage, for example, provides immediate power conversion and such a plant, the first in this country, is being built at Ffestiniog.

Advanced reactors

Within the last two or three years an appreciable advance has been made in projected reactor coolant temperatures and experiments have confirmed many of the design proposals. The result is that a number of both gas-cooled and water moderated reactor projects yielding high coolant temperatures are now beyond the project stage and will in the relatively near future permit advanced steam cycle conditions.

Details of the advanced gas-cooled reactors are given in Table 1 and it will be seen that the coolant outlet temperatures range from 930°F for the British AGR to as high as 2400°F for the experimental American 'Turret' reactor project in which it is proposed to use unclad fuel elements with continuous fission product removal.

Both the high temperature gas-cooled reactors (HTGR) have very similar operating conditions but differ appreciably in output (the Dragon project is experimental and the heat is dissipated). The US HTGR employs a 40 MW steam turbine and the steam conditions are comparable to those of the smaller modern conventional plants.

The maritime gas-cooled reactor (MGCR) has two gas turbines, one driving the gas compressors, whilst the other would drive the ship's propeller through a reduction gear unit (*13*). The use of gas turbines in such a scheme is justified when bulky heat exchange equipment must be omitted, even if some efficiency loss is inevitable.

From Table 1 it is clear that reactor coolant inlet temperatures are also moving upwards and that a much greater freedom in steam cycle selection will result, with full feed heating, high single pressure evaporation, and an appreciable degree of superheat. By simplifying the cycle in this way and reducing the size of the equipment through higher operating pressures the main object of reducing capital cost will be achieved, with considerable reduction in operating costs through higher efficiency.

TABLE 1 *Advanced gas-cooled reactors*

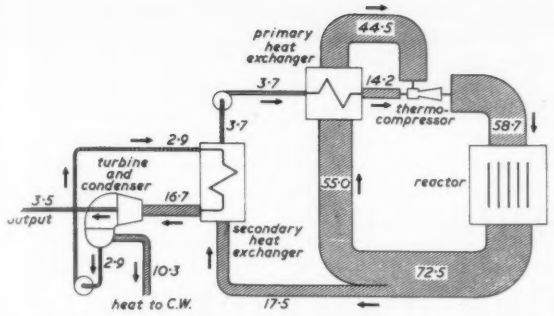
	AGR WINDSCALE	HTGR 'DRAGON'	HTGR GEN. ATOMIC	MGCR GEN. ATOMIC	TURRET LOS ALAMOS
Power.					
Thermal MW	100	20	115	50·34	3
Electrical MW	27·3	heat rejected	40	22,000 shp	heat rejected
Moderator	Graphite	Graphite	Graphite	BeO	Graphite
Coolant	CO_2	He	He	He	He
lb/in²	285	294	300	778	500
°F inlet	480/620	662	660	753	1600
°F outlet	930/1070	1382	1380	1300/1500	2400
Type of turbine	Steam	None	Steam	Gas	None
Inlet, lb/in²	650	—	1450	739	—
°F	850	—	1000	1300/1500	—
Completion, approx.	1961	1963	1963	1964	1962

It may be practicable with these reactors to employ gas turbines to provide power for the gas circulators through the medium of a self-contained turbo-compressor unit. By using the reactor heat energy more directly in this way, the temperature drop in the heat exchangers necessary for the auxiliary steam conversion would be eliminated and the equipment itself reduced, with a consequent gain in power and a reduction in first cost.

Against these advantages must be set the inherently lower efficiency of the gas turbine cycle compared with the equivalent steam cycles unless the latter, like the Dungeness or Tokai-Mura systems, is noncondensing and works purely with steam in its superheated, gaseous form. The possible complications connected with large industrial turbo-compressors would also have to be considered and it therefore seems unlikely that the gas turbine will supersede the steam turbine as main power producing plant within the foreseeable future.

Nuclear superheat

Developments in the field of water moderated reactors have been of considerable interest lately. These concern



Combined flow and heat stream diagram for the Vickers marine reactor, the numbers show the approximate heat flow in Btu/s × 10^4, feed heating and all losses being neglected (Fig. 4)

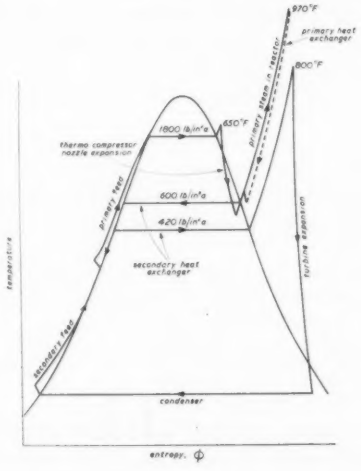
direct nuclear superheating of the working steam in the reactor core and have been proposed in the USA with light water, in the UK with heavy water, and in Russia with graphite moderators. Their particulars are summarized in Table 2.

All of these plants are as yet in the design or building stage but indications are, from initial experiments, that the objects can be achieved.

Of particular interest is the largest of the US projects, the Pathfinder (*14*) in which the outer part of the core serves as evaporator whilst the inner part will superheat the steam. As a development of this scheme, a proposal has been made for a 330 MWe in which one reactor would produce superheated steam and a separate reactor would act as reheater, working at a lower pressure. With the omission of the heat exchangers, a large saving in capital cost and also a far more compact layout can be achieved.

The Vickers marine reactor (*15*) shows two interesting features. Although the fuel element temperature and pressure are high, the heavy water moderator is kept to a low temperature (70°C) and at atmospheric pressure. No boiling takes place in the core, the steam coolant merely being superheated and conversion of water to steam is carried out in a heat exchanger.

The heat stream diagram shows that most of the heat passes through the reactor circuit without performing useful work. It should be remembered, however, that the heat values represented by the width of the streams are



Temperature-entropy diagram for the Vickers marine reactor (Fig. 5)

TABLE 2 *Reactors with nuclear superheat*

	BORAX V	BONUS Puerto Rico	PATH-FINDER	VICKERS MARINE REACTOR	RUSSIAN URAL STATION
Power, Thermal MW	20/40	50	203	150	285
Electrical MW	—	17	66	—	100
Moderator	H_2O	H_2O	H_2O	D_2O	Graphite
H_2O Coolant, lb/in²	600	900	600	600	2265
°F core outlet	—	534	489	970	655
Superheater, lb/in²	—	850	540	—	1605
°F outlet	850°	900°	825°	—	950°
Completion, approx.	1961	1963	1962	—	1961

All these reactors feed steam directly to the turbine except the Vickers reactor which at the moment has an indirect cycle, but.. could be modified to direct cycle operation

based on a given datum (32°F). This means that a large flow of coolant at moderate temperature would still show an appreciable heat content and the heat added by fission in the reactor core may even be a relatively small proportion of it.

The second feature is the introduction of a thermo-compressor which replaces the coolant circulators and, it is claimed, shows an appreciable saving in pumping power, in addition to dispensing with mechanical moving parts. A combined flow and heat stream diagram and the thermodynamic cycle are shown in Figs. 4 and 5.

The Russian system (*16*) for a 100 MWe plant, to be eventually a 400 MWe station in the Urals, will comprise both evaporator and superheater sections separately in the same graphite moderated core. The projected steam conditions, as seen from Table 2, are very advanced. Water is allowed to boil in a central tube, surrounded by fuel elements, and the steam/water mixture generates saturated secondary steam. This is led via the superheater section directly to the turbine.

If these projects are successful, the steam cycles of conventional stations will be very closely approached, if not attained, in large nuclear stations in the 1970's. The future aim must be to reduce manufacturing costs and increase both size and ratings of nuclear stations in order to achieve maximum economy.

Acknowledgement

The authors gratefully acknowledge the help and advice of the Nuclear Department of Kennedy and Donkin.

References

1. Wootton, W. R., 'Steam Cycles for Nuclear Power Plant', Temple Press Ltd. 1958.
2. *Nuclear Power*, 1960, **5**, July, 73–75.
3. Wood, B., 'Wetness in Steam Cycles', I.Mech.E. Paper, Feb., 1960.
4. Kramer, A. K., 'Boiling water reactors', Addison-Wesley, 1958.
5. Bird, R. H., *Nuclear Power*, 1960, **5**, March, 110–113.
6. Wootton, W. R., 'The integral nuclear steam generator', Vienna Conference on Small and Medium Power Reactors, Sept. 1960.
7. Theunissen, F. A. P. M., *Nuclear Power*, 1960, **5**, July, 76–79.
8. Kay, J. M., and Hutchinson, F. J., 'The Pressurized Water Reactor as a Source of Heat for Steam Power Plants', I.Mech.E. Paper, Dec., 1955.
9. Milne, G. R., Stroller, S. M., and Ward, F. R., 'The Consolidated Edison Company of New York Nuclear Electric Generating Station', Geneva 1958, Paper 15/P/1885.
10. Benzler, H., 'The Choice of Steam Cycle in a Combined Nuclear and Thermal Power Station', *Atomkernenergie*, 1959, Feb.
11. Hiedl, H., 'Steam Cycles in Atomic Power Stations', World Power Conference, Vienna, 1956.
12. Marguerre, F., and Marguerre, F., 'The Application of Heat Storage in Nuclear and Conventional Power Stations', Paper VIII, World Power Conference, Madrid, 1960.
13. Browne, H. L., 'Maritime Gas-cooled Reactors', Am. Nuc. Soc. Philadelphia Symposium 1960.
14. Civilian Power Program (Part IV), TID-8519, USAEC, Feb. 1960.
15. *Nuc. Eng.* Vol. 4 No. 39, June, 1959.
16. Civilian Power Reactor Program (Part III), TID-8518(5), USAEC, 1960.

Since it was proposed at Geneva, further work on this reactor design method has shown that it can form a permanently useful addition to existing techniques

The thermal simulation of flux distribution

by R. BERENBAUM, Ph.D., G. K. CAULTON, B.Sc., and D. S. GREENAWAY, B.Sc.
of the Research and Development Laboratory, Atomic Power Constructions Ltd

AN ANALOGY EXISTS between the temperature distribution in a cooling solid and the one-group neutron flux distribution in a reactor. This analogy has been used by Mossop and McGhee (*1*) to examine the effectiveness of different arrangements of control rods in a particular design and these authors also discussed a number of other possible applications of the method.

This paper describes the development of theoretical and experimental techniques, which have extended and established the usefulness of the analogy, and some results for a particular design problem.

One group neutron theory

The neutron flux distribution in a bare, homogeneous, thermal reactor in a critical state is given by:

$$\nabla^2 \phi_n (r) + B_n^2 \phi_n (r) = 0 \qquad (1)$$

The flux distribution ϕ_o corresponding to B_o^2 can be shown to be the only persistent distribution, all higher modes decaying with time. At criticality B_o^2 can be related to the nuclear properties of the reactor by

$$B_o^2 = \frac{k_\infty - 1}{M^2} \qquad (2)$$

Cooling equations

In an isotropic solid with no heat sources the equation of conduction of heat is given by:

$$\nabla^2 \theta - \frac{1}{K} \frac{\partial \theta}{\partial r} = 0 \qquad (3)$$

θ may be written $\theta = \Theta_\rho (\rho)\, \Theta_t (t)$ (4)

whence, from equation (3):

$$\frac{\nabla^2 \Theta_\rho}{\Theta_\rho} = \frac{1}{\Theta_t K} \frac{\partial \Theta_t}{\partial t} \qquad (5)$$

THE BASIC ANALOGY

The temperature distribution in the fundamental mode of a cooling wax model can be a good approximation to the neutron flux distribution in a thermal reactor as derived from one group theory.

This makes is possible to obtain the neutron distribution where simple analytical solutions of the diffusion equations do not exist. For example it may be particularly useful in dealing with difficult control rod geometries.

As Θ_ρ and Θ_t are linearly independent, each side of equation (5) is constant and putting

$$\frac{1}{\Theta_t K} \cdot \frac{\partial \Theta_t}{\partial t} = - C_n^2 \qquad (6)$$

it follows that $\Theta_t = \Theta_o e^{-K C_n^2 t}$ (7)

and $\nabla^2 \Theta_\rho + C_n^2 \Theta_\rho = 0$ (8)

i.e. at any chosen time

$$\nabla^2 \theta_n + C_n^2 \theta_n = 0 \qquad (9)$$

The formal analogy

The experimental technique is based upon the formal analogy between equations (1) and (9). In particular, the lowest eigenvalue C_o^2 of equation (9) will correspond to the mode which decays most slowly (from equation (7)) so that by measuring temperatures in the solid a sufficiently long time after cooling begins, the distribution obtained will correspond only to this mode. Hence, provided that it is possible to satisfy boundary conditions in the thermal model corresponding to the neutron flux boundary conditions in the reactor, the form of the persistent flux distribution in the critical reactor may be inferred, since the temperature distribution, θ_o, represents the same solution to the same wave equation as does the flux distribution ϕ_o.

Moreover, because of the correspondence between B_o^2 and C_o^2 (again, provided that the boundary conditions are analogous) the evaluation of C_o^2 (from a measurement of the asymptotic rate of cooling of a model using equation (7)) gives a measure of B_o^2, the geometrical buckling for the reactor represented. In fact $B_o^2 = C_o^2/g^2$, where g is the scaling factor, reactor dimension divided by model dimension.

Boundary conditions

The discussion is in terms of the large cylindrical reactor but extension of the method to other shapes is straightforward.

In the simple neutron diffusion theory, the negative logarithmic gradient of the flux at the boundary of the diffusing medium is a constant i.e.

$$-\left[\frac{1}{\phi} \frac{\partial \phi}{\partial r}\right]_{r=R_o} = \frac{1}{\lambda} \qquad (10)$$

λ, the extrapolation length, being derived from a more detailed study of the neutron behaviour near the boundary

of the reactor, and chosen so that at a few neutron mean free paths within the medium, the simple diffusion equation gives the correct neutron distribution.

In a similar way, near a change of the properties of the diffusing medium—say at the core-reflector interface, the asymptotic neutron distribution in the core obeys the wave equation (1), provided that a boundary condition of the type of equation (10) is assumed at the interface with the appropriate choice of λ.

To use the thermal analogue to solve equation (8) for a simple cylinder the procedure would be to bring the model to a uniform temperature θ_o and then to allow it to cool in a constant temperature surround θ_c using forced convection by a liquid coolant to extract the heat.

The radial flow of heat per unit area from model to coolant is given by

$$-q\left(\frac{\partial\theta}{\partial\rho}\right)_{(\mathrm{Lt}\ \rho\to a)} = h(\theta - \theta_c) \qquad (11)$$

If the temperature θ is defined such that $\theta_c = 0$ then

$$\mathrm{Lt}_{\rho\to a}\left(\frac{\partial\theta}{\partial\rho} + \frac{\theta}{(q/h)}\right) = 0 \qquad (12)$$

Comparing equations (10) and (12) it is seen that if θ can be considered to be the analogue of neutron flux then (q/h) is the analogue of the extrapolation length λ and the boundary conditions in the two cases are formally equivalent.

Difficulties

However, it is difficult to use this precise equivalence, because the heat transfer coefficient, h, depends on coolant velocity and it is very difficult, experimentally, to maintain a uniform flow rate of just the required amount over all the model surfaces. Instead, therefore, a further approximation is made.

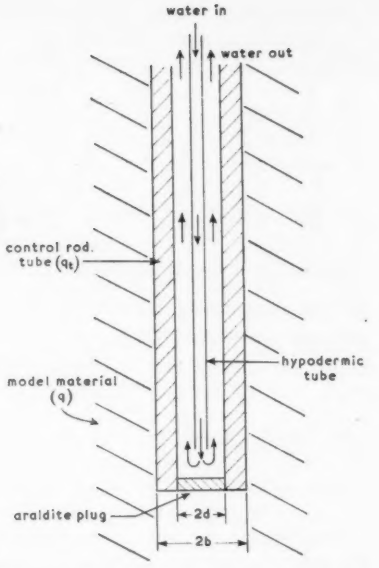
Referring to the neutron boundary condition at the core-reflector surfaces, $\partial\phi/\partial r$ varies only slowly with r and a good approximation is to accept the boundary condition.

$$\mathrm{Lt}_{r\to R}\ \phi = 0 \qquad (13)$$

where $R = R_o + \lambda$. For a cylindrical, graphite reflected and moderated reactor, λ is found to be of the order of $0{\cdot}1\ R_o$. The corresponding boundary condition in the model is to have zero excess temperature at the boundary

SYMBOLS

ϕ_n	*neutron flux*
B_o^2	*buckling*
r	*reactor spatial co-ordinates*
t	*time*
k_∞	*infinite multiplication factor*
M	*migration length*
θ	*temperature*
K	*thermal diffusivity*
ρ	*spatial co-ordinate in model*
C_n	*eigenvalue of cooling equation*
R_o	*radius of reactor*
λ	*extrapolation length*
q	*thermal conductivity of model*
q_t	*thermal conductivity of tube in simulated control rod*
h	*heat transfer coefficient*
a	*radius of model*
s	*radius of control rod*
λ'	*extrapolation length of control rod*
b	*radius of simulated control rod in model*
g	*overall scaling factor* $= \dfrac{\text{reactor height}}{\text{model height}} = \dfrac{\text{reactor radius}}{\text{model radius}}$
f	*control rod scaling factor* $= s/b$
Y_0, Y_1	*Bessel functions of second kind*
β^2	*radial buckling in reactor with single control rod*
d	*internal radius of tube in simulated control rod*



A tube of low thermal conductivity material inserted in a hole in the model simulates a control rod (Fig. 1)

of a model scaled from radius R (rather than R_o, i.e. the extrapolated radius governs the size of the model) and the problem is now to achieve zero excess temperature at its boundary. A close approximation to this condition can be achieved by very fast coolant circulation and a low model conductivity. (Note: the foregoing remarks have considered radial boundary conditions, the axial problem is, of course, essentially the same).

Simulating control rods

The boundary condition at a cylindrical control rod of radius s may be written as

$$\mathrm{Lt}_{r'\to s}\left(\frac{\partial\phi}{\partial r'} - \frac{\phi}{\lambda'}\right) = 0 \qquad (14)$$

where r' is measured from the centre of the rod and the extrapolation length λ' is determined by the nature of the rod; while if a coolant liquid at a constant temperature is passed through a cylindrical hole in a cooling solid the boundary condition may be expressed as

$$\mathrm{Lt}_{\rho'\to b}\left(\frac{\partial\theta}{\partial\rho'} - \frac{\theta}{\sigma}\right) = 0 \qquad (15)$$

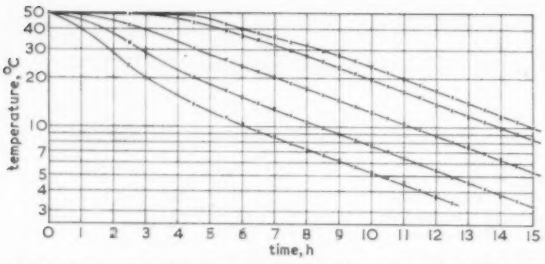
Here the radius of the hole is b and σ is given by q/h. It follows that if the scaling factor s/b equals the overall scaling factor (g) and the extrapolation length is similarly scaled (i.e. $g = \lambda/\sigma$) then the long term temperature distribution in the model will correspond to the reactor flux distribution, as before.

However, it is experimentally difficult to achieve these requirements in a simple manner, for the following reasons.

(i) If g is chosen so as to make the model of reasonable size then the required value of b is inconveniently small.

(ii) The corresponding value of σ is such as to require a slow flow of coolant which must be accurately controlled and of uniform temperature along the entire length of the hole.

As far as (i) is concerned this may be overcome by taking $s/b = f \neq g$; it can then be shown, by considering the case of a reactor with a single central control rod, that the flux distribution in the reactor is still represented



Typical set of cooling curves for five thermocouples (Fig. 2)

by the temperature distribution in the model provided that σ is chosen such that

$$\sigma \triangleq \frac{Y_0(\beta s) - Y_0(\beta g b) + \beta \lambda' Y_1(\beta s)}{\beta g Y_1(\beta g b)} \qquad (16)$$

(As a check on this result we may notice that for the case $f = g$, this does reduce to $\sigma = \lambda'/g$.)

The difficulty referred to in (ii) has been overcome by using a tube of a material of low thermal conductivity inserted within the hole in the model (see Fig. 1). If then the inner surface of this tube is maintained at $\theta = 0$ by a strong flow of coolant it can be shown that

$$\underset{\rho' \to b}{\text{Lt}} \; \theta / \frac{\partial \theta}{\partial \rho'} = b \log (b/d) \qquad (17)$$

Where d is the internal radius of the tube. Also

$$\underset{\rho' \to b^+}{\text{Lt}} \left[q \frac{\partial \theta}{\partial \rho'} \right] = \underset{\rho' \to b^-}{\text{Lt}} \left[q_t \frac{\partial \theta}{\partial \rho'} \right] \qquad (18)$$

whence, from equations (15), (17) and (18)

$$\underset{\rho' \to b}{\text{Lt}} \left(\frac{q\theta}{\sigma} - \frac{q_t \theta}{b \log (b/d)} \right) = 0 \qquad (19)$$

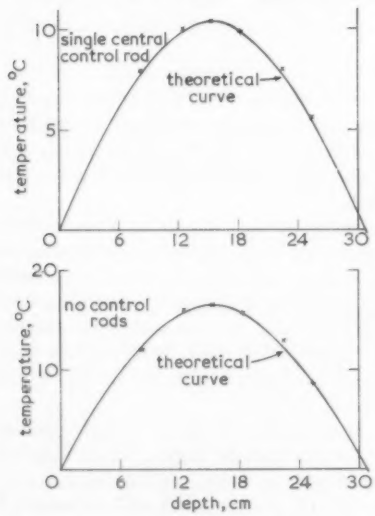
therefore

$$\sigma = (q/q_t)\, b \log (b/d) \qquad (20)$$

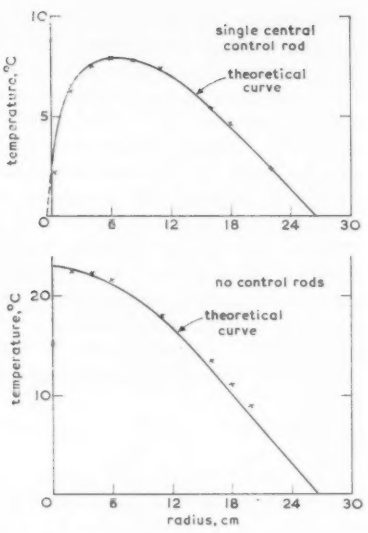
i.e. σ then depends only on the thermal conductivities and the dimensions involved and is independent of time and temperature. Hence, in principle any σ can be represented.

The model

The modelling material used for the experiments described here was an investment casting wax; this was easy



Axial 'flux' distributions for the one rod and bare cases; the measurements were taken after 10 h of cooling and show good agreement with the theoretical curve (Fig. 3)



Radial 'flux' distributions (Fig. 4)

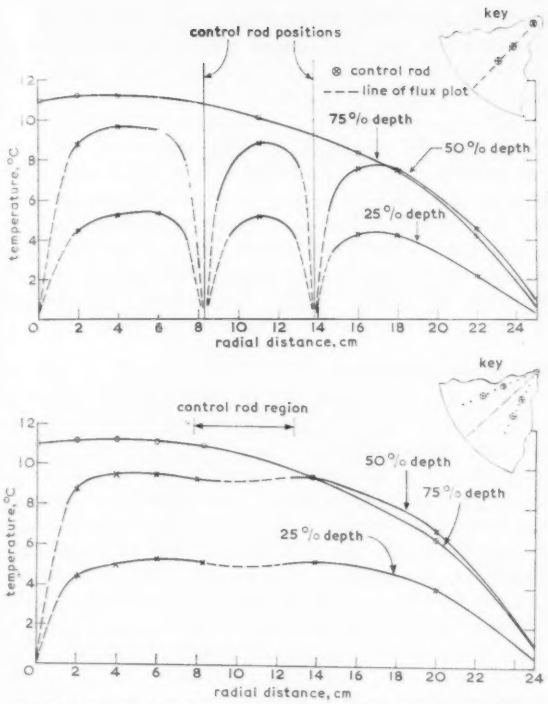
to machine, reasonably strong and resistant to thermal shock and could be heated to about 80°C without softening. Also it could be mixed with aluminium powder in order to alter thermal conductivity, and thus provide an extra variable parameter for the attainment of correct control rod extrapolation lengths. Alternatively a casting resin may be used with its advantages of greater strength and heat resistance but rather greater difficulties of manufacture.

A cylindrical model of radius 26·6 cm and height 30·7 cm was made of this material with 10% by weight of aluminium powder added and 100 thermocouples were embedded at a variety of depths and radial and circumferential positions. The choice of 10% addition of Al powder was made to facilitate the simulation of control rods. The optimum quantity of additive was also governed by the requirement that the model cool fairly slowly. This allowed accurate temperature measurement over a long period, about 20 h for the model described, and also allowed sufficiently rapid heat removal for attainment of the correct boundary conditions. The model rests on a spiral in a cylindrical container which leaves a gap of about 1 cm around its circumference and 2 cm above and below it. Another spiral supports the lid clear of the model. There are two coolant inlets tangentially at opposite sides of this tank and outlets at the centres of the top and bottom. The pump used gave calculated coolant velocity in the region of 10 cm/s over the surface of the model. The natural choice of coolant was water and this was maintained at a constant temperature of 0°C during cooling by a large quantity of melting ice.

The cylindrical tank itself was wholly submerged in a tank of water also at 0°C during cooling; water to the pump was drawn from this tank and returned to it after passing over the model. A second pump supplied water to the control rod holes in a similar manner, the holes being lined with polythene tubing (the thermal conduc-

TABLE 1 *Theoretical and measured bucklings*

	B^2 THEORETICAL, cm^{-2}	B^2 MEASURED, cm^{-2}
No control rod case	0·0187	0·0202 ± 0·0020
1 control rod case	0·0207	0·0220 ± 0·0020
17 control rod case		0·0298 ± 0·0020



Radial 'flux' plots for the seventeen rod case (top) along control rod radii (bottom) between control rod radii (Fig. 5)

tivity, with the thermal conductivity of the wax/aluminium model, being such as to lead to a desired control rod extrapolation length). For 'partially inserted' control rods (i.e. not fully through the model) hypodermic needles were inserted down holes of the correct depth and cooling water pumped down them and up the sides.

Experimental technique

Nine thermocouples, made up from the same wire as that used for the model, were calibrated before use, and the results obtained were sufficiently close together to justify using this calibration for all the thermocouples. Considerable effort was devoted to ensuring accurate measurement of temperature and eliminating stray contact e.m.f.'s etc. because, as previously mentioned, only the latter parts of the cooling curves bear relation to reactor behaviour; consequently the temperature differences between the model and the coolant are small and sensitive to quite small errors of measurement. A digital voltmeter was used for measuring the thermocouple outputs and this enabled the 100 readings to be made in about 7 min.

Results obtained

Three sets of results are described:

(1) Bare cylinder
(2) Cylinder with single central control rod, fully inserted
(3) Cylinder with 17 rods, one at the centre and two rings of 8, the central rod and outer ring being inserted to a depth of 60% and the inner ring to 50%.

The purpose of the first two sets of measurements was to compare the theoretical flux distributions in these cases, where calculation is possible, with those deduced from the model. Also, by comparing the deduced bucklings in these cases with the theoretical values, to examine the accuracy with which this quantity could be determined. The third case is an example of the type of problem which the analogue might be used to solve.

Figure 2 shows a typical set of cooling curves for five thermocouples; it is seen that after initial curved portions, the latter parts of the plots of log (temperature) against time are closely linear and parallel.

It is over this region that the fundamental solution only is found and it is seen that the extent of persistence of harmonics varies, as is expected, with position in the model.

Axial and radial temperature distributions for the bare and one rod cases are shown in Figs. 3 and 4. These were taken 10 h after cooling had begun; at this time the cooling curves indicated that only the fundamental mode was present, but the temperatures were still sufficiently high for errors of measurement to be small. Comparison with the theoretical curves shows good agreement.

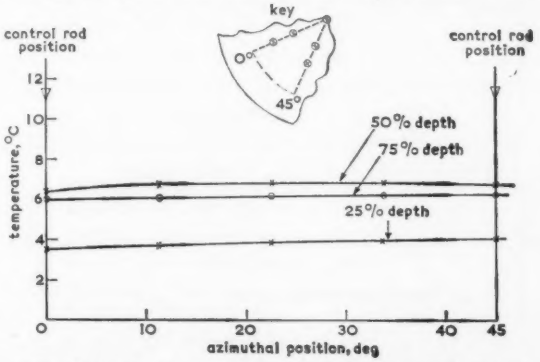
For the bare and one control rod reactors simulated, the geometric bucklings can be calculated and these were compared with the values deduced from the linear portions of the model cooling curves (using an independently measured value for the thermal diffusivity of the model material). The results are shown in Table 1 together with the measured value for the seventeen rod model. The agreement is within the experimental uncertainty in each case where the buckling can be calculated.

The experimental uncertainty quoted arises from

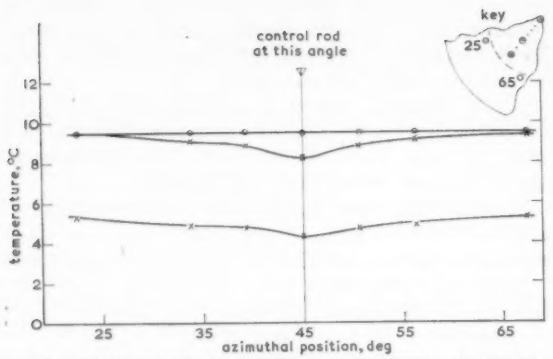
(*a*) the spread of slopes among the 100 cooling curves from each model (although the standard error of the mean value was quite small).
(*b*) the experimental uncertainties in determining the thermal diffusivity and thermal conductivity of the model material and the thermal conductivity of the rod lining material.

The uncertainty arising from the measured thermal diffusivity is by far the largest factor and if this is neglected then the estimated error is thought to be not more than $\pm 2\%$ on each measurement of buckling. This means that changes of buckling when a given model is altered should be quite closely determined; thus the percentage change in buckling in going from the model with no control rods to the one with a single central rod was measured as $9\% \pm 3\%$ which compares well with the theoretical change of 10·1%.

Figure 5 shows typical radial flux plots for the seventeen rod case. It is seen that there is some uncertainty in drawing the plots near control rods because there were



Azimuthal plots at a radius well outside the outer ring of control rods (Fig. 6)



Azimuthal ' flux ' plot at a radius near a control rod (Fig. 7)

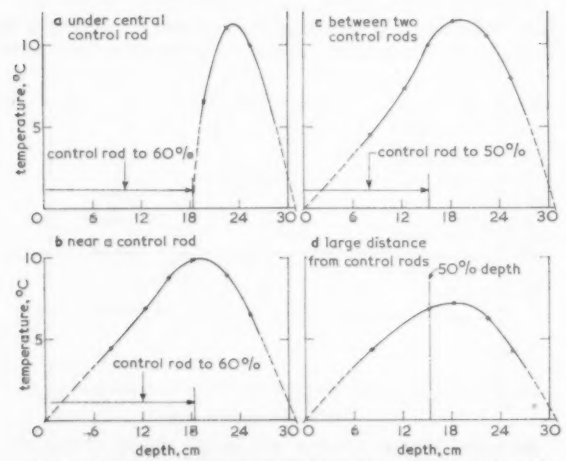
not usually thermocouples close to the rods. While it is difficult to show that the extrapolation distance attained is exactly that desired, there can be no doubt that, provided a fast flow of water is maintained, the model temperature must approximate to zero at a control rod hole. This was also directly demonstrated by the results for the one rod case (where a thermocouple was between the lining of the hole and the model), which showed that the simulated flux did, in fact, fall close to zero at such a rod.

Significant features of the flux plots

Although this model does not represent an actual power reactor (being unflattened), there are a number of significant features which can be deduced from a study of the flux plots.

The first point which should be noted is the consistency of measurements obtained from similarly placed thermocouples; this can be seen from Fig. 6, which shows azimuthal plots at a radius well outside the outer ring of control rods. The relatively small differences in reading and the smoothness of the curves suggest that significance can be attached to control rod ' dips ' in flux, seen in plots such as those in Figs. 5 (bottom) and 7.

A further point of general interest is the considerable flux displacement caused by the partially inserted control rods. This is apparent from the asymmetry of the azimuthal plots at 25% and 75% depths in Fig. 6 and the effect is shown in more detail in Fig. 8*a*, *b*, *c* and *d*, which are axial flux plots at various positions in the model. It is



Axial ' flux ' plots at various positions in the model (Fig. 8)

found, by measuring the areas under the curve of Fig. 8*d*, that even far from any control rod the integrated flux in the lower half of the simulated reactor is some 25% greater than that in the top half.

With the large number of thermocouples in the model it was possible to obtain a close estimate of the total integrated flux by graphical interpolation and integration. If this technique was applied to a practical reactor then the flux plots could be normalized by relating the integrated flux to the power output. This model could also be used for the study of different systems of control rods, with the effectiveness of each arrangement being assessed in terms of changes in buckling and flux shapes.

Future development

The most useful extension of the technique would be to the study of flattened reactors. Homogeneous flattening can be simulated readily by making a composite model in which the central portion has a higher diffusivity than the outer portion and models of this type have been successfully made. However, the results obtained would not necessarily be of value. For example, if a very high diffusivity were employed in the central portion the reactor simulated might be ' over flattened ' with flux peaks outside the flattened region; such a reactor might easily be one which required massive enrichment to make it critical.

The model, of course, always simulates a critical reactor, so that the measured geometric buckling must equal the materials buckling of the reactor simulated. If this materials buckling cannot be attained with the system envisaged (e.g. natural uranium, graphite moderated) then the results are of only limited usefulness. Thus, the accurate simulation of a reactor must be by a process of trial and error in which the degree of flattening and control rod absorber is adjusted until the measured geometric buckling agrees with the materials buckling calculated for the system used. To do this with composite models of the type described above would entail the building of many models. However, there is no reason, in principle, why flattening cannot be simulated by the use of additional cooling holes in the model; that is, the direct representation of flattening bars with appropriate extrapolation lengths. Adjustment of buckling would then be a matter of varying the depth and number of flattening bars simulated and this could be done on a single model with many holes in it in the possible positions for flattening rods and control rods. The effect on flux shape of alterations in control rod pattern etc. could then be studied in great detail, with the knowledge that the alterations necessary to maintain a constant value of the buckling were those that would be needed in practice to maintain the reactor at criticality.

There are, of course, experimental difficulties involved in building a reactor analogue with the necessary large number of holes and with thermal properties such that the various extrapolation lengths could be simultaneously simulated, but no fundamental problems have so far been encountered.

Acknowledgments

The authors would like to thank Messrs. P. Ashworth, W. E. Etherington, B. Savage and R. Clayton, all of whom have materially contributed to the project.

Reference

1. Mossop, I. A., and McGhee, J., ' Use of Analogue Wax-model Methods for Reactor Calculations '. Paper 17. Geneva Conference (1958).

Compatability problems and nuclear considerations restrict the choice of brazing alloys

Brazing Fuel Elements for the OMR

by N. W. D. CHRIMES, B.Sc., A.I.M., Hawker Siddeley Nuclear Power Co. Ltd.

ONE OF THE FUEL ELEMENT designs proposed for organic moderated reactors uses pellets of UO_2 of 2Co enrichment canned in stainless steel tubes $\frac{1}{2}$ in. i.d. × 0·0068 in. thick made to specification BS970 En 58B. Nineteen of these tubes are fabricated in a bundle surrounded by an outer coolant tube the arrangement being shown in Fig. 1. This particular design is based on the requirement of the structure to withstand quite high shock loads i.e., 15*g* along the bundle axis and 9*g* laterally. Terphenyl, the organic moderator/coolant is circulated through the interstitial channels at a temperature of about 330°C and a pressure of 100 lb/in²g. A general account of factors determining the design of organic moderated reactor fuel elements has been given previously (*1*).

The problem

The general problem was to join the tubes together so as to provide a rigid bundle while at the same time keeping the quantity of steel used to a minimum owing to neutron absorption considerations. This involved the use of triangular sectioned tubular spacer pieces also 0·006 in. thick fixed to the fuel tubes at approximately 7-in. intervals. The development of a satisfactory joining method became the principal problem.

Initially, some form of spot welding was considered, but it was apparent that while this method could be used for the fabrication of sub-assemblies, accessibility and strength considerations would preclude it from being used for the final joining operations inside the bundle. It was therefore proposed that though spot welding would be used primarily to locate the position of the spacer pieces, the necessary strength would be obtained by furnace brazing using pre-placed inserts of either wire, shim or paste. A similar design, though employing a different method of applying the brazing alloy, had been used for the fuel element of the 'Yankee' pressurized water reactor (*2*). For the OMR fuel element the filling of the tubes with the pellets of UO_2 and the subsequent welding on of end caps would be the final stage in the process, i.e., after brazing.

Selection of brazing alloy

At an early stage in this project, the attributes of a suitable brazing alloy were listed as follows:

(i) Satisfactory strength at temperatures up to 425°C corresponding to normal operational temperatures (continuous exposure) with ability to stand short term excursions up to 600°C. A shear strength of about 6–8 tons/in² at this temperature would probably be satisfactory. This should preferably be accompanied by reasonable ductility.

(ii) Compatibility with the organic moderator/coolant under operational conditions.

(iii) Lack of aggression towards the stainless steel base metal at the brazing temperature. This implies only slight penetration (up to an absolute maximum of 0·001 in. in this instance).

(iv) Satisfactory nuclear properties.

(*a*) Low absorption cross section so as not to affect neutron economy appreciably.

(*b*) No formation of active isotopes with long half lives from any of the constituent elements. This would only be relevant if some corrosion by the organic coolant occurred and activity was transferred to other parts of the system.

A survey was made of brazing alloys with melting points above 800°C, and eventually it was decided that the palladium base alloys developed by Mond Nickel Co. were most likely to be satisfactory (*3*) though their properties did not always comply exactly with these requirements.

Data on the alloys chosen for further examination are given in Table 1.

TABLE 1 *Properties of palladium-base brazing alloys*

ALLOY	COMPOSITION %	BRAZING TEMP., °C	NEUTRON ABSORPTION CROSS-SECTION barns
CPNM2	Ni-15, Mn-10, Pd-20, Cu-55	1110	5·7
NMP1	Ni-48, Mn-31, Pd-21	1200	8·0
PN1	Ni-40, Pd-60	1250	6·7

Properties of brazed joints

Salient results obtained during a short list programme were as follows:

(i) Ambient temperature shear tests showed that future occurred preferentially by tearing through the tube and not through the brazing metal.

(ii) Joint filling properties were satisfactory and gaps of the order 0·001/2 in.

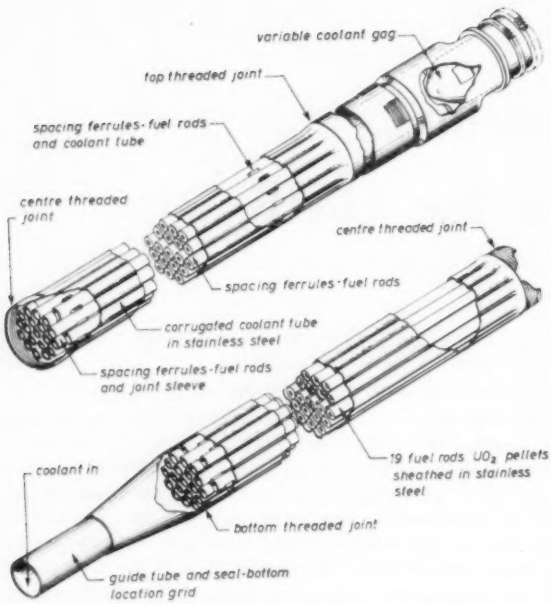
(iii) Voids were almost entirely absent.

(iv) The average depth of penetration was 0·0003 in. 5% of section thickness.

(v) Weight gains in corrosion tests were slightly under $\frac{1}{4}$% after 30 days at 400°C in terphenyl and only copper from the CPNM2 was detected in any appreciable quantities in the residual terphenyl.

(vi) Substantially longer than normal brazing times did not cause complete penetration.

(vii) Prolonged exposure (4 h) at temperatures of 1200°/1250°C resulted in a substantial decrease in ultimate strength and elongation values of the stainless steel and appreciable grain growth occurred (*4*), see Fig. 2.


variable coolant gag
top threaded joint
spacing ferrules-fuel rods and coolant tube
centre threaded joint
centre threaded joint
spacing ferrules-fuel rods
corrugated coolant tube in stainless steel
spacing ferrules-fuel rods and joint sleeve
19 fuel rods UO_2 pellets sheathed in stainless steel
coolant in
bottom threaded joint
guide tube and seal-bottom location grid

Fuel elements consist of pellets of UO_2 in stainless steel tubes, there are nineteen tubes in a bundle surrounded by an outer coolant tube (Fig. 1)

Brazing the fuel element assembly

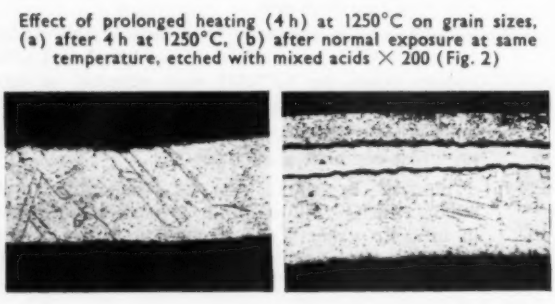
After the preliminary experimental work it was decided to braze a complete experimental fuel element. Sub-assemblies consisting of several spacer pieces attached to single fuel element tubes were prepared by spot welding. The brazing alloy in the form of wire 0·020 in. diameter was placed in position by clipping it round the edge of the spacer pieces, the material chosen being PN1 alloy. The sub-assemblies were then placed in a jig. It was realized that with a jig of this type it would not be possible to maintain close tolerances on the joint gaps but this was not regarded as essential.

The brazing was to be done in an atmosphere of hydrogen and the assembly and jig were placed in a horizontal position in a stainless steel cylinder, provision being made for the location of several thermocouples. The actual brazing operation was carried out using a gas-fired mufflle furnace. The complete brazing cycle took about 8 h with about 1 h near the brazing temperature of 1250°C to allow for the slight lack of temperature uniformity between the two ends of the furnace.

When the outer container had cooled down to room temperature, the fuel element bundle and jig were withdrawn. Its general appearance was proof that a satisfactory atmosphere had been maintained and, though the jig had bowed slightly, satisfactory adhesion had occurred in the majority of locations; in no case had complete perforation of the stainless steel by the brazing metal taken place. The general inference was that the operation had been successful apart from the distortion and the expected grain growth.

It is suggested that some improvement may be effected by the adoption of the following measures: (*a*) brazing in the vertical position, (*b*) use of reinforced ceramic jigs to provide lateral support and prevent buckling, (*c*) use of a specially designed furnace that would give rapid but controlled heating.

Effect of prolonged heating (4 h) at 1250°C on grain sizes, (a) after 4 h at 1250°C, (b) after normal exposure at same temperature, etched with mixed acids × 200 (Fig. 2)



Non-destructive inspection

In the quantity production of a number of fuel elements by this process, one of the most important considerations would be the choice of a suitable non-destructive test method to ensure:

(*a*) that there was no actual perforation of the tube wall,

(*b*) that there was no area of local weakness where the effective wall thickness had been drastically reduced.

In the first instance, a helium leak test using a mass spectrometer would probably be the most satisfactory method. To detect areas of local weakness in the tube wall, a hydraulic pressure test would appear to be the only satisfactory method, preferably followed by the helium leak test.

General conclusions

The use of ternary and quaternary palladium bearing brazing alloys was shown to be feasible for this complex type of fabrication though compatibility problems and nuclear considerations impose further restrictions on the choice. Allowance should be paid to the decrease in strength properties of the steel due to exposure at high temperatures. It was shown that the maintenance of close tolerances was not essential to secure adhesion. It is suggested that the various practical problems of which the prevention of distortion was the most pronounced be overcome as a result of practical experience. It is also probable that both vacuum and hydrogen brazing would be satisfactory.

One of the most acute problems likely to be encountered in practice would be the development of a satisfactory non-destructive testing method to ensure that the fuel element tubes had not been perforated or substantially weakened.

Acknowledgments

The author wishes to thank the Development and Research Department of the Mond Nickel Co., for technical advice and the provision of brazing materials, Delaney-Gallay Ltd, for carrying out experimental work and Marston Excelsior Ltd, for work on the brazing of a complete assembly. He also wishes to thank colleagues at the Hawker Siddeley Nuclear Power Co., for assistance in carrying out this work.

References

1. Wyatt, O. H., O.M. Fuel Elements, *Nuc. Eng.*, 1960, **5**, Feb., 64–66.
2. King, P. P., and McGeary, R. K., Braze Bonding Stainless Steel Fuel Elements for Nuclear Reactors, Welding Research Supp., 1959, **38**, June, 241–246.
3. Cibula, A., The soundness of High Temperature Brazed Joints in Heat Resisting Alloy, B.N.F.M.R.A. Research Report 1193, June, 1958.
4. Hoppin, G. S., and Bamberger, E. N., Effect of Hydrogen Brazing on the Properties of High Temperature Alloys, Welding Research Supp., 1959, **38**, April.

In contrast to the UK's two university reactors the USA has now over forty. Its third university reactor conference is reported here

University Reactor Conference

by A. C. HUGHES, Hawker Siddeley Power Co. Ltd.

THE FIRST UNIVERSITY to operate a reactor—North Carolina State College—has so far used them to train over 300 degree students. Dr Arthur Menius, representing the college, opened the Conference proper by describing how the first reactor, an aqueous homogeneous 'water boiler', chosen because details of this type were the first to be released by the USAEC, has led to a modified 500 W version NCSC-IV, to be used mainly as a training reactor.

Another reactor, NCSC-III, a 10 kW pool type, was completed in March this year and will be used mainly for research.

So far in its programme, NCSC has used the reactor in B.S. courses (194 students) M.S. (122 students) and Ph.D. courses (11 students), mainly in the subject of reactor physics. The expected utilization of the new reactor is as follows:

teaching 14·9%; calibration and maintenance 12·7%; unsponsored research (i.e. M.S. and Ph.D. thesis) 63·1%; short courses 9·3%.

The average operating power to date in the training programme has been 385 W.

Dr Uhrig of the University of Florida also described a 10 kW reactor, the first Argonaut-type to be installed in a university, which has now been operated for about a year. The training programme consisted mainly of a two semester M.S. degree course for which thirteen students were now enrolled. The first semester was of a general nature (neutron detection techniques, etc.) but the second semester was devoted entirely to the reactor which was used (*a*) as an instrument to be investigated in its own right, e.g. approaches to critical, control rod calibration, reactor kinetics, and (*b*) as a source of neutrons for experiments in radioactivation analysis, spectrum measurements, etc. The research programme was now being formulated and would initially consist of work on reactor parameters by noise analysis and by observation of the response to cyclic reactivity changes.

The Worcester Polytechnic Institute has operated a 1 kW pool reactor exclusively as a training facility since December 1959, since Worcester is primarily an undergraduate school, and twelve students are trained at one time in three groups of four students on a rotational basis. The reactor staff is small and consists of the Professor plus one laboratory assistant with additional part-time operators brought in from time to time from amongst the faculty members. With the reactor used and operated in this way, the operating costs are low compared with most installations and do not exceed $8000/year (exclusive of salaries).

Research programmes

The second session was devoted to reactors being used primarily for research and where the teaching programme, if any, plays a secondary role. These ranged in size, complexity and cost, from the little AGN 211 at Rice University to the 1 MW heavy water reactor at the Massachusetts' Institute of Technology.

The University of Michigan operates a 1 MW pool reactor at its Phoenix Memorial Laboratory. This project was financed entirely by public subscription and even for operating costs, the college does not have to seek support by outside contracts. The reactor started up in September 1957 and was operated at 100 kW for about a year before the power level was increased to 1 MW. Dr William Kerr stressed that careful planning was necessary to fully utilize such a reactor. The reactor has been used for thesis work by chemists (4), physicists (2), chemical engineers (3) and by numerous students of the Nuclear Engineering Department on such topics as:

1. Inelastic scattering by time of flight
2. Bubble formation rate by statistical analysis
3. Reactivity effect of moderator expulsion
4. Measurement of parameters by stochastic processes etc.

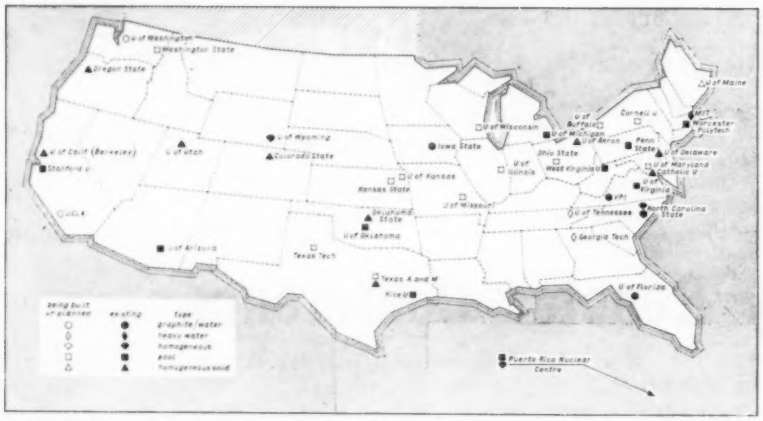
Mr Forrest Remick, in describing the programme at Pennsylvania State

The Conference . . .

More than two hundred scientists and engineers from 14 countries attended the third University Reactor Conference, held at Gatlinburg in August. It was sponsored by the USAEC, the Oak Ridge National Laboratory, the Oak Ridge Institute of Nuclear Studies and the Oak Ridge section of the American Nuclear Society. The previous conferences, held at Oak Ridge and Gatlinburg respectively, were in 1954 and 1956

The topics reviewed . . .

- *progress since 1956*
- *status of university reactor programmes*
- *experience with research and training reactors*
- *reactors available*
- *university requirements*
- *acquiring a reactor*



University reactor installations, existing, planned or under construction in the USA (Fig. 1)

University, showed how an intensive programme could be carried out on a medium powered reactor. Nine industrial firms were currently using the 100 kW pool reactor although such work was not solicited and priority was given to university workers. The reactor was now operated on two shifts with the second shift on a 50% load. Additional senior staff were being recruited to allow this load to increase to 100%. Some 35 projects were currently under way and the reactor was usually fully committed for two months ahead. There were, on the average, about 35 people per day in the reactor building, the main users being the departments of Chemistry and Physics with the College of Agriculture close behind. More than seventy reports had been published, the most outstanding line of research being that pursued by the College of Agriculture on photo-synthesis.

Ambitious project

Probably the most ambitious reactor project in any university is that at the Massachusetts Institute of Technology. A heavy water reactor of 1 MW output, based on CP5 (at Argonne) but designed by university staff, will shortly be uprated to 3 MW. The programme associated with it is equally ambitious and last year 86 students used it for thesis work. It is the only university reactor equipped with a medical facility and recent work has included neutron therapy experiments.

Professor Thompson, who has been with the project since its inception, is still strongly in favour of universities having reactors and to doubters of the wisdom of this policy, he compares the 68 facility holes in the MIT reactor with the one hole in the cyclotron. He points out, however, that there must be a good balance between reactor and university and the reactor 'dog' must not wag a university 'tail'.

The MIT reactor first reached full power in February 1959 and is now averaging 100 MWh/week. Figure 2 shows the arrangement of the experiments around the reactor and gives a good idea of the intensity of the MIT programme. Such a programme is, of course, expensive and costs about $300,000/year to maintain (including reactor operating costs). Although this is only a small proportion of MIT's annual expenditure on research, Professor Thompson still has difficulty in financing his programme.

BACKGROUND

The first university reactor in the world was designed by Dr. R J. Murray, at the University of North Carolina and went critical in 1953 with fuel loaned by the USAEC (and incidentally created a policy of fuel cycle assistance by the US Federal Government). This step stimulated a lot of thinking among college people and indirectly among government agencies concerned with atomic energy education. The first announcement of government policy was made at the 1st University Reactor Conference when it was announced that secrecy barriers were to be broken to permit reactors at universities, and the principle of fuel cycle assistance by the USAEC was stated publicly. One of the main topics at that conference was 'why a university reactor?' and this question, pertinent at the time, is still valid today even though there are now more than 40 university reactors (see Fig. 1) in the USA alone

Whether accidental or contrived, the arrangement whereby Dr Thomas Leland followed Professor Thompson provided a striking contrast in programmes. The reactor at the Rice University is an example of shoestrings and simplicity. This reactor, a below-ground version of the AGN 211, has a maximum flux of less than 10^9 n/cm²/s but is nevertheless used for research work which is yielding important results. It has been used by the Physics Department in the development of energy dependent scintillation counters for neutron detection. The Chemistry Department made a study of the effect of irradiation on solid-state catalysts—particularly zinc oxide—and found it to be a fertile field in which little work had been done previously. This report prompted Professor Thompson to remark, in a later discussion, that while some people associated more and more research with higher and higher flux the real trend ought to be towards more and more research with lower and lower flux.

Safety proposals

Later sessions covered the safety aspects of university reactors and the determination of university needs for a nuclear reactor. Speaking on the former topic, Dr Clifford Beck of the Hazards Evaluation Branch of the AEC pointed out that with the advent of competent commercial organizations offering proven designs, the main safety emphasis had shifted from design and construction to operation. He strongly advised universities to employ at least one person full time, since part time members were always subject to pressures from their other activities. The operating staff should have their duties clearly defined and a detailed operating manual should be provided. People of authority up the chain of command should be available for advice and there should be an arrangement whereby members of other departments should be used for cross-checking proposals. Dr Beck strongly advised universities to get together and draw up some standards of operation and procedure. A committee containing people now operating reactors would be experienced and free the 'red tape' surrounding Government Agencies.

The second topic was covered by Professor Andrew Robeson of the Virginia Polytechnic Institute, whose determination had led to the selection of a reactor, and Professor Isbin of the University of Minnesota, whose deliberations had led to the rejection of a reactor as a useful instrument.

Professor Robeson thought that Universities did not need $M1 facilities to do good research work, particularly in the subject in which he was most interested, reactor physics,

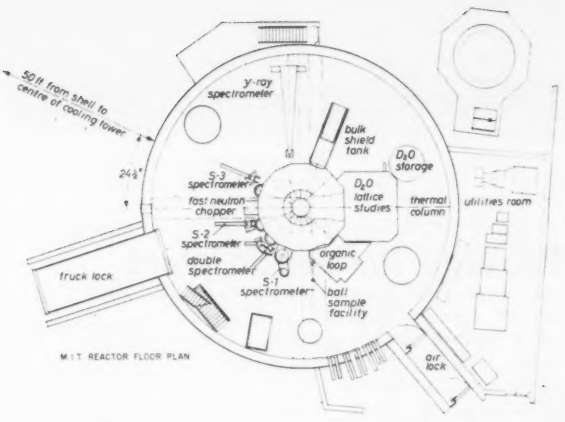
In this field, many data were required to tie up loose ends and students were delighted to find that they could improve on existing data and, in many cases provide information that was not otherwise available. Virginia Polytechnic Institute had thought hard before procuring an Argonaut-type reactor (they also possess a graphite sub-critical assembly, an analogue computer, an enriched polyethelyne sub-critical assembly and a Cockroft-Walton accelerator) and had decided to go ahead even before they knew that they were going to 'run into so much assistance'.

Professor Isbin's optimizations had, however, led him to the conclusion that the best reactor for Minnesota would be of zero power, zero size. The University of Minnesota, had one of the largest graduate schools in the country and their experience in all departments was that formal graduate laboratory work should be cut to a minimum. They had no separate department for nuclear engineering and did not award degrees in that subject in the engineering department. All their teaching requirements could be met with heat transfer rigs, a Co-60 source and a subcritical assembly which together allowed for a well-integrated programme.

Dr Joseph Dietrich of the General Nuclear Engineering Corporation compared the usefulness of light and heavy water reactors as high flux facilities. He showed that while there were some differences, e.g. greater fast flux for a given power in light water reactors, superior collecting power of the thermal column in a heavy water reactor, these differences were not sufficiently marked to make one type generally superior. Unless the cost of heavy water was such a significant factor as to tip the scales against it, the choice would depend on the reactor programme.

Iowa State University owns an Argonaut-type reactor and Professor Glen Murphy discussed some of the problems involved in procuring a reactor—not least among which being the choice of colours for the reactor and building, with the contractor pressing for an on-the-spot decision! Among the more serious items are the preparation of operating manuals, operating schedules and the training of operators. Operators could gain useful experience by participating in the construction of the reactor. A safety committee had to be established, emergency procedures drafted and numerous items examined to see that they met the requirements of the AEC Licence (e.g. fuel storage area must not present a criticality hazard).

Dr Lawrence Quarles, Dean of the School of Engineering, University of Virginia, described the construction of a 1 MW pool reactor designed by the University with the aid of architectural and technical consultants. The University acted as its own prime contractor, employing and supervising numerous sub-contractors, so that the capital cost was kept to a minimum. The project received a major set-back when the first attempt was made to fill the pool tank. The leakage rate was so high that it was impossible to raise the water level even with additional pumps. Dr Quarles showed a number of striking photographs taken at the height of this disaster and also showed how they eventually developed a technique for pumping concrete into the gaps in the pool walls and finally achieved a watertight system. This one fault put the project back a full year, increasing the construction time to about two and a half years. The total cost (including buildings and engineering services, but excluding university salaries) was around $800,000. Included in the plan was an instrument laboratory, a radiochemical laboratory and a workshop.



Layout of experiments around the 1 MW heavy water reactor at MIT (Fig. 2)

During the conference, the USAEC announced that they would not finance any more teaching reactors (there are already 30 such reactors in operation). In addition the National Science Foundation has not budgeted for funds for new research reactors in the coming financial year. Thus any applicant for funds would have to compete with other research projects. This seemed sensible, since most university research reactors (i.e. reactors of 10 kW and upwards) were fairly new and had not yet reached their full potential. The Foundation had therefore adopted a policy of 'wait-and-see', but hoped their aid programme would not be long interrupted.

Future role

The closing session of the conference included two panel discussions. One was on 'the future role of university reactors', with a panel drawn from the universities and the National laboratories, and the other on the availability of reactors from industry, with a panel of representatives from thirteen reactor manufacturers. The first panel included reactor protagonists and antagonists and it is not surprising that they failed to present a coherent plan for the future. A novel approach was taken by Dr Taecker of Argonne National Laboratory. He suggested that the increasing costs of research apparatus, high flux reactors, synchrotrons, etc. were more than most universities could bear, and he suggested that there was a need for a few post-university institutes.

Conclusions

Many of the university reactors are being put to good use and, in some cases, the output, both of research work and of students, is outstanding. It becomes obvious from an examination of the discussions at the conference that this output is related to the quality and enthusiasm of the staff and may be independent, to some extent, of the power level of the reactor. Funds for university reactors (at least for the initial cost) have been too readily obtained and some reactors have been procured for scanty or non-existent programmes. This is probably why, in spite of the close proximity of many US universities to one another, the sharing of reactors between universities is almost unknown. Only in tiny Rhode Island (with five degree awarding establishments), has such a scheme been considered.

In the UK several committees are vetting university programmes and it is likely that reactors will be authorized only where a substantial teaching and research programme exists. UK universities which survive this scrutiny might well be envious of their American counterparts on two scores, both significantly affecting operating costs: the generosity of the USAEC in fabricating, lending and reprocessing fuel free of charge; and the reasonable insurance rates, about $20,000/year, for comprehensive cover for a 1 MW reactor, for example.

Package irradiation plant

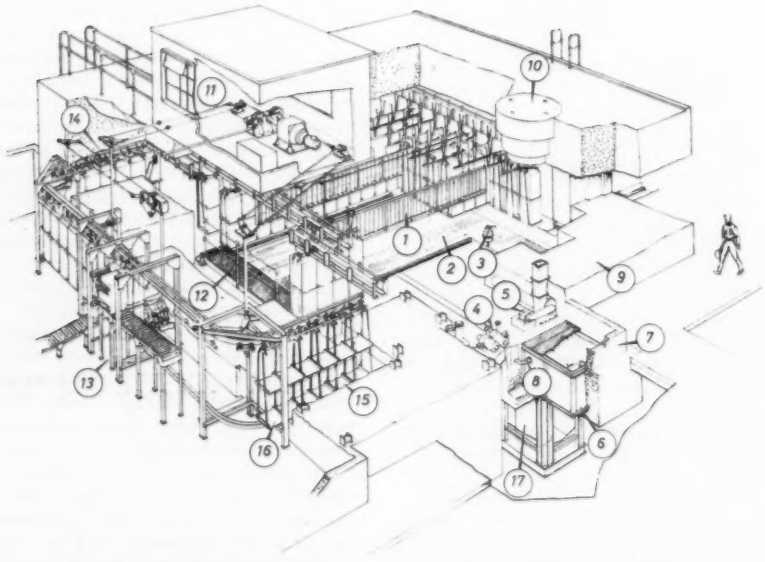
industrial design developed

FOLLOWING closely the development by the AEA of a pilot irradiation plant at Wantage (*August*, 1959, pp 110-11), Vickers-Armstrongs (South Marston) Ltd have developed, from their own design, a package irradiation unit to satisfy a commercial requirement for the large scale processing of pre-packed surgical and medical goods or contaminated raw materials for the textile industries. Design and control is such that day-to-day operation may be carried out by semi-skilled personnel with no danger from irradiation risks.

Using a 500,000 curie source, and a sterilizing dose of 2·5 rads, the throughput is 90,000 lb per week at an 0·2 density. With higher density materials, throughput can be increased to 120,000 lb. The following figures give some idea of package output rate: 4 ft × 3 ft × 3 ft packages—one every 44 min; 18-in packages—8/h; 12-in. packages—19/h.

In contrast to the Wantage design, the gamma cobalt-60 source is split into two parallel planes for improved source utilization. The basic source unit, 1½ in. × 2 ft long, has a nominal value of 3000 curies and there is a maximum space provision for 1 megacurie of new rods, thus enabling the source strength to be maintained by the addition of 12·5%/year for eight years without the removal of any of the initial source.

Packages for sterilization are conveyed past the source plaques by means of an overhead monorail. Each carrier on the monorail contains two packages, one above the other, and each passes through the cell twice to obtain uniform dose distribution. Each time the carrier emerges from the cell, by means of automatic transfer equipment, the bottom package is removed and the top one is placed in the bottom position, a new package being placed on the top position. Dosage in the vertical plane is thus maintained sensibly constant.



VICKERS-ARMSTRONGS PROCESSING UNIT. 1. cobalt-60 source 2. pond 3. raft-mounted flood lights 4. water filtration pumps 5. ventilation unit 6. make-up tank 7. main plant room 8. weir tube 9. shielding 10. roof plug 11. traversing drive mechanism 12. rail-mounted servicing platform 13. load/unload and escalator transfer station 14. carrier entry labyrinth 15. carrier exit labyrinth 16. package carrier 17. flask

The operation of the monorail system can be either electrical or hydraulic. In the case of the electrical system where only low h.p. motors are required, the push-rod mechanisms are operated by cams. In the case of a hydraulic source, the motors will be used to charge hydraulic accumulators sequenced to hydraulic jacks to control the operation.

The sterilized packages can be passed straight through the carrier exit labyrinth to emerge at the load/unload escalator, or input and output storage conveyors can be supplied, thereby allowing the installation to operate without attention for periods of up to 17 hours.

Safety valves for the AGR

relay operated

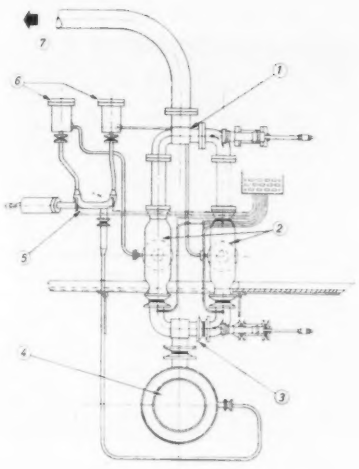
In selecting the safety valves for the AGR at Windscale, the normal direct spring-loaded valve was considered to be inadequate on account of the relatively small sealing force, provided by the difference between the spring load and the working pressure acting on the valve lid area. Furthermore, a spring fracture would result in coolant discharge.

Cockburn's design for a fullbore relay operated safety valve was therefore selected by the UKAEA as the one most suitable for operation under normal and abnormal conditions. In this design, the load, due to the full working pressure acting on the valve lid, actually contributes to the sealing of the valve faces. In addition to the normal metal-to-metal valve faces, the main safety valves are provided with rubber 'O' rings and, while the CO_2 working temperature is 760°F, it is estimated that the maximum temperature of 300°F, obtaining in the static gas zone of the valve faces, will permit the use of such rings.

In deciding to fit this additional sealing device, the Authority have taken into account the fact that a safety valve blow-off would, in any case, necessitate a reactor shut down, thus providing an opportunity for the expendable sealing rings to be replaced.

Another problem to be overcome in valve selection was the design of the pilot valve [(6) in the Figure on p 103] that actuates a full-bore safety valve (2). As this is normally direct spring loaded, the problem was resolved by the choice of deadweight loaded pilot valves, comprising a group of cast iron weights.

During normal reactor operation the change-over valves(1),(3), of the safety valve unit are in the mid-position, thus providing 100% margin over the required safety valve capa-



1. Exhaust changeover valve (hydraulically linked) 2. main fullbore safety valves 3. inlet changeover valve (hydraulically linked) 4. reactor coolant duct 5. pilot valve changeover valve 6. pilot valves 7. exhaust to chemical extraction plant

One of the five complete safety valve units designed by Cockburns for the AGR

city. During testing, the changeover valves, which are synchronised and fitted with panel indication lights showing the mid and terminal positions, are actuated by a Lockheed cylinder. By isolating one main safety valve (2) and the corresponding pilot valve(6) from the main coolant system, an independent CO_2 supply, controlled by a small bellows-sealed stop valve, facilitates testing.

Nuclear heat exchangers

India's new plant

India is to have a new plant capable of handling the fabrication of Berkeley or Dungeness type heat exchangers. In co-operation with the Indian Sugar and General Engineering Corporation, Isgec, of the Punjab, John Thompson Ltd. are to build a new plate shop which should be in operation by early 1961. With the ultimate plan of design and manufacture of water-tube boilers with a working pressure of up to 1900 lb/in², the 390 ft × 75 ft plate shop will be equipped with overhead electric travelling cranes of 15 and 25 tons capacity.

Equipment to be supplied by Thompsons will include a 12 ft × 1¼ in. cold working plate bending unit; a 400 ton, 4 column hydraulic press; a double-ended stress relieving furnace, 36 ft × 14 ft × 14 ft; a 20 ft × 12 ft plate heating furnace, and a 6 ft diameter vertical boring machine. Other equipment to be shipped to India will include a Unionmelt welding head equipped with turning rolls, and a hydraulic tube bender capable of handling 5-in. tube.

The Indian company will co-operate in the building of the furnaces and it will itself supply such equipment as planing, boring, milling and drilling machines.

High pressure joint

uniformly stressed

Richardsons Westgarth have developed a new type of expansion joint for high pressure ducting in gas-cooled reactors.

Expansion joints for this purpose have to be capable of transmitting the axial duct thrusts, amounting in some cases to over 1,000,000 lb while, at the same time, allowing a predetermined amount of angular deformation. The difficulty that faces existing designs is the necessity of transmitting the peripherally uniformly distributed axial duct forces into one axial plane, thus requiring extremely heavy structures stressed mostly in bending. Furthermore, these designs deal only with deflexions in one plane, so that any misalignments at right-angles to the normal deflexion plane impose uncontrolled loads on the components of the circuit.

The new type of restraint which will be first used in the Trawsfynydd Atomic Power Station, deals satisfactorily with all aspects of the problem. Working entirely on elastic deformation principles, it consists of a multiplicity of high tensile bars, arranged in two groups into two frusto-conical assemblies, and spaced uniformly around the periphery of the duct; the axial forces transmitted are therefore entirely uniform.

In the axial direction the joint behaves as a stiff connexion, but it can deform angularly by transverse bending of the bars. The deformation of the restraint is achieved by pure elastic deformation of the restraint bars, so that the forces involved are both accurately predictable and not variable in time. Furthermore, the complete rotational symmetry of the restraint makes it equally flexible in any direction.

The full-scale rig for the new expansion joint on which fatigue tests were carried out

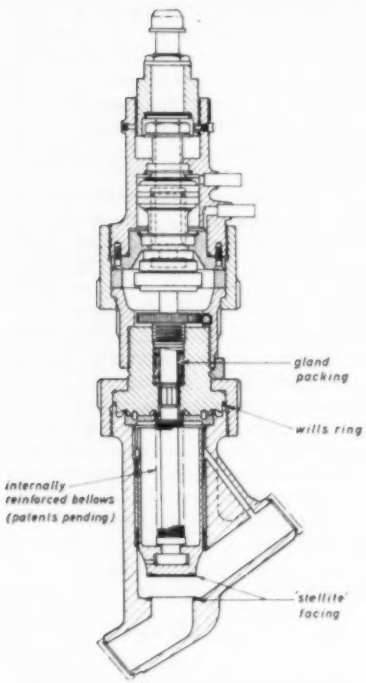
A centering device, connecting the two duct stub ends, ensures that no torque loading can be applied to the convolutions, and equalizes the deflexions of the two sets of bars under conditions of steeply changing bending moment along the duct. The shear force accompanying such a change of bending moment is taken entirely by this device, leaving the bellows free of this additional loading. A further advantage of the design is that the completely transparent and accurately calculable stress system allows a close approach to an ideal shape in the tension bars.

Special valve types

bellows sealed

For some of the developments in the nuclear power industry only short production runs are required for certain parts. This is especially true of the valves required for reactor experiments and prototypes, and many firms are not willing to spend a lot of money on development when there is no likelihood of large-scale production. One firm, Teddington Aircraft Controls Ltd, who have had previous experience as valve manufacturers to the aircraft and missile industries, have had some recent success in the nuclear field in the design and construction of specialized valves. In the past 18 months they have prepared over 350 different designs, and recently included a range of standard valves from ½ in. to 12 in. N.B. using interchangeable parts. It is hoped by this method to reduce the number of types and at the same time cover the greatest range of applications. Two of the most interesting valves will be going on the test loops of the AGR Windscale. These are 6-in. parallel slide valves, hydraulically operated and bellows sealed, and 6-in. motorized butterfly valves, also bellows sealed. Both these valves are for CO_2 service and are fabricated from Cr-Mo. They will operate at 320 lb/in²g, 475°C. Both are operated by a crank action, and an ingenious system of nesting the bellows keeps the operating part of the valves compact.

They have also developed a range of bellow-sealed globe valves in a ½ in.–2 in. range (see figure). The bellows here is internally reinforced (patents pending) and is designed for a



This 2-in. globe valve designed primarily for PWR application is suitable for most fluids and gases and can be made in a range of materials

working pressure of 3000 lb/in² and a test pressure of 4500 lb/in², the operating temperature being 343°C. These valves have been designed as isolating valves for PWR applications but are suitable for fluids and gases. They are designed to be either mechanically, hydraulically, electrically, or manually operated and can be made in stainless steel, Cr-Mo, Iconel, or Nimonic.

Sintered reactor materials

ductile form

Powder metallurgy techniques are being applied by the Sintercast Division of Chromalloy for the production of aluminium and stainless steel/boron composite materials that are readily predictable, reproducible and homogeneous.

'Binal', for example, a uniform dispersion of boron carbide in an aluminium matrix, can be produced in continuous strip form which can be wound into coils and cylinders, or fabricated into many other shapes. With up to 5% boron, 'Binal' can be used as a burnable poison, or with 12% (by weight) boron carbide, it can be used for shielding or for control.

'Bo-stan', a high-temperature reactor control material, consists of a carefully balanced dispersion of boron in stainless steel. After sintering and hot-working, the composite is as fully dense, ductile and strong as a cast alloy of equivalent composition. It is of particular interest in pressurized water reactors, where problems of oxidation and high temperature prohibit the use of aluminium and its alloys. Presently, up to 2% boron can be incorporated, but larger boron contents are soon expected to be feasible.

During sintering, a diffusion process bonds the metal particles to form a solid, though porous composite. To achieve full density, compacts are hot-worked a few times, after which final fabrication is performed by cold-rolling, sizing, or machining.

'Binal', a new type of sintered and wrought material, is flexible enough to be wound into a coil

Plutonium fuel element fabrication

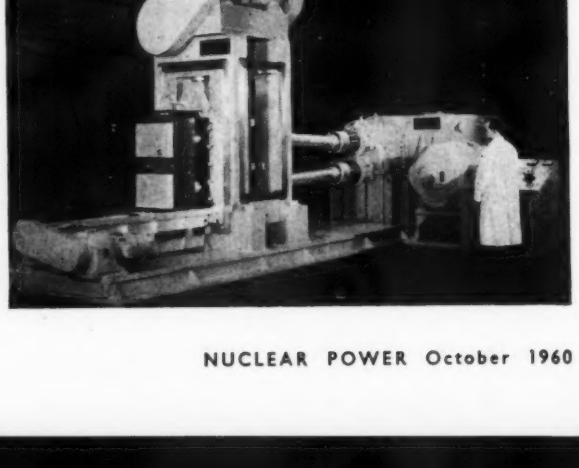
remote controlled milling

The world's first rolling mill for plutonium alloys, designed to operate entirely by remote control within an airtight steel enclosure vessel, has been completed. Built by Loma Machine Manufacturing Co., Inc. of New York, it is to be installed at the Hanford Works in Washington for the production of fuel elements for the Plutonium Recycle Test Reactor.

The 'PRTR' project is a long-range experimental programme expected to lead to the use of plutonium as a fuel for nuclear reactors. The first fuel loading for the reactor will comprise 85 elements, of which 25 will contain plutonium fuel in the form of plutonium-aluminium alloys while the remaining 60 elements will contain uranium dioxide.

It is necessary to process the metal in an inert atmosphere of argon. The new machine therefore has been designed for complete enclosure within a fabricated steel hood or glovebox which will be evacuated to a pressure of 1μ Hg before the start of operation. It is then back-filled to atmospheric pressure with argon in order to obtain an atmosphere of acceptable purity.

To avoid insulation breakdowns in the motors caused by the ionization of argon, both the main mill motor and auxiliary motors for screwdown and roll changing drives are mounted outside the hood, to operate in air. An outstanding feature of the mill is its power-operated roll change mechanism which facilitates removal and replacement of various types of rolls within the glovebox area. The roll change mechanism not only accelerates changeover of rolls from 2-high



The new Loma machine is a 20 in. wide 2-high/4-high combination rolling mill employing 3 in. dia. work rolls and 14 in. backup rolls

to 4-high operation, and vice versa, but provides safe, remote control handling of rolls assumed to be contaminated beyond tolerance once they enter the mill enclosure. In conventional practice such processing operations would call for a 2-high hot breakdown mill, a 2-high cold intermediate mill, a 4-high cold finishing mill and a 2-high rod rolling mill.

The machine has a roll separating force capacity of 800,000 lb. at a speed of 100 ft/min. The remote control power screwdown system consists of two 5 h.p. gearmotors offering alternate speeds of $\frac{1}{4}$ in. and 4 in. per minute. An electro-magnetic clutch is provided to connect the two screwdown motors when simultaneous adjustment of mill settings on both sides is required.

A slideway and slide mechanism is provided for roll changing, and a lead screw driven by a 5 h.p. motor actuates the slide which inserts or withdraws the entire roll assembly as a unit. Lever-actuated cam-locks release the upper roll chocks from the screwdown mechanism. Cam-actuated gibs are withdrawn to release the roll assembly from the mill housings.

Plutonium-in-air activity

rapid warning monitor

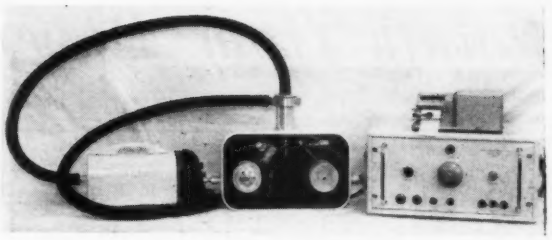
A monitor that gives rapid warning of the release of plutonium into the atmosphere by continuously sampling air for plutonium alpha activity, has been developed at AWRE, Aldermaston. The plutonium dust particles are impacted on to a zinc sulphide coated film that is observed continuously with an alpha scintillation counter. The impactor collects particles of about 1 micron in size, such as those of plutonium, readily. Smaller particles like those of radon or thoron decay products, are swept through. The discrimination efficiency in favour of the larger particles is about 10 to 1.

Sampling is carried out for pre-set periods (e.g. 10 minutes) and the integral count recorded at the end of each period. The sampling unit incorporates the demountable impactor assembly, film spools, scintillation counter, actuator mechanism and safeguard circuits. The impactor is connected to a blower unit which gives a sampling rate of 18–20 ft^3/min.

The remote control and alarm unit, which is rack mounted, contains four main circuits: (1) timing, (2) scaling, (3) alarm trip, and (4) e.h.t. and h.t. power supplies.

During operation, the pulses from the scintillation counter are integrated at the remote scaler, the alarm trip circuit being pre-set to operate at a known number of counts (equivalent to a particular concentration of plutonium in air). If and when this integral number is reached the alarm is given. If the pre-set integral count is not reached in the pre-set period, the timing circuit shuts off the blower and the scintillation film moves forward to expose a new section of zinc sulphide to the impactor. The scaler is reset, the blower restarted, and a new count commenced.

The monitor incorporates a 'fail-safe' provision should no counts be integrated during the pre-set period or if there should be a failure of the film drive.



Believed to be the first of its type in the world, the AWRE plutonium-in-air monitor consists of (left to right) a blower unit, an air impactor unit and an alarm monitor

IN BRIEF

TRIGA REACTOR ADAPTED General Dynamics have developed a *pulsing* Triga reactor designed to produce very intense but self-limiting pulses of neutron and gamma ray radiations for short periods at repeated intervals. In addition to its capability for controlled pulsing, the reactor will have a steady-state operating level of 100 kW. The primary purposes of Triga Mark-F will be the study of the effects of radiation on various types of electronic components and circuitry used in Army Ordnance equipment, including tests of equipment while in actual operation.

The reactor core for the radiation facility differs from the cores of the standard Triga reactors in that it will contain more fuel elements of a special design, in a new core configuration. In addition, the reactor will use water rather than graphite as a reflector.

SUPER-CRITICAL REHEAT UNIT International Combustion are to build a once-through reheat boiler unit for the CEGB to operate at super-critical pressure. The unit will be capable of producing sufficient steam for a 375 MW turbogenerator, and is designed to operate at a pressure of 3650 lb/in^2g with the h.p. steam temperature at 1110°F and the reheated steam temperature at 1055°F. The steam output will be 2,5000,000 lb/h.

Full automatic control of the unit will be provided both for the feed water, steam temperature, reheat temperature and by-pass system.

NUCLEAR COAL GASIFICATION A recent conceptual design study of the US Bureau of Mines shows an economic advantage in applying nuclear heat to the gasification of coal. The design uses three 250 MWt slightly-enriched, gas-cooled reactors with the helium coolant passing through an exchanger type gasifier. Here coal and steam are reacted to form carbon monoxide and hydrogen.

Calculations show that 311,000 lb/h of low quality coal could produce 14 million ft^3/h of carbon monoxide-hydrogen mixture, with further processing to produce 90 million ft^3/day of high Btu gas.

HIGH TEMPERATURE SEMICONDUCTOR Single crystal whiskers of magnesium oxide that range from 3 to 4 mm in length and from 1 to 5 mils in cross-section have been produced by Semi-Elements. Apart from providing the facility for further research into the characteristics and properties of magnesium oxide, the development should ultimately reveal a semiconducting material having high mobility and high energy band gap properties, plus the advantage of being able to perform under high temperature conditions not possible with other semiconductors.

USSR WELDING TECHNIQUES Interesting welding techniques that have been developed in the USSR include flat coiled and welded aluminium pipeline that can be unrolled on site and restored by compressed air to give continuous runs up to 2000 ft long. Again, there is the use of water vapour as a shielding atmosphere for arc welding, in circumstances where the transport of conventional shielding gases would be prohibitive.

With capital equipment at a premium and heavily worked, great emphasis has been placed on repair, rebuilding and hard facing by welding using 'fire cracker' techniques with horizontal flat and 'powder tape' electrodes.

STEEL SCALE DETECTION A quick, simple and inexpensive method of checking the completeness of removal of mill scale from steel plate has been developed by 'Shell' Research. As received, steel plates are covered with mill scale, or magnetic iron oxide, which in itself is immune to corrosive attack. However, for two reasons, the mill scale is undesirable. Firstly, it presents a surface which is not a good base for paint, and secondly, if it is scraped off, heavy pitting occurs.

The method, devised at Thornton for overcoming this problem, requires only the application of a solution of copper sulphate to the freshly blasted steel surface, an operation which takes only a few seconds. Areas entirely free of mill scale become coated with copper, while any scale shows up as a dark area against the copper background.

Points from Papers

reports, meetings, conferences

OXIDATION OF GRAPHITE

This theoretical study of depth of oxidation in graphite (UKAEA report DEG 148(CA) by M. H. Dodson) gives the concentration distribution of oxygen in a block of pile graphite expressed in terms of L the 'depth of oxidation' [$L = (z/k_v)^{0.5}$ where z is the effective diffusion coefficient of oxygen through pores in the graphite, and k_v is the rate constant expressed in terms of volume of oxygen consumed].

It is concluded that if L is very much less than the linear dimensions of the block, the total rate of oxidation is the same as would occur if the oxygen penetrated freely to a depth L below the whole surface of the block—there being no oxidation below this depth. The rate at a depth x below the surface is proportional to exp. $(-x/L)$.

Similar results apply approximately for the reaction between carbon dioxide and graphite.

Measurements of the rate of oxidation of large graphite specimens with simple configurations are recommended, in order to check the theory under operating conditions.

REACTOR NOISE

Two papers from AEE Winfrith describe F.M. record/replay systems for the harmonic analysis of nuclear reactor flux noise. One, 'Frequency spectrum of Calder Hall reactor noise', AEEW M19, is by J. D. Cummins with computation by E. R. Yolland. The spectrum was obtained by analysing a tape recording of the backed-off power of No. 1 reactor, Calder Hall. The noise power for this reactor is stated to be due mainly to modulations of the power level by reactivity variations caused in turn by gas temperature changes. These gas temperature changes are caused by a cyclic variation in the feedwater regulator to the heat exchanger. The other paper, 'A record/replay system for the harmonic analysis of nuclear reactor flux noise', AEEW M33, by L. A. J. Lawrence and E. R. Corran, describes work done in connexion with the automatic control system of the research reactor Dido. The methods are fully described in both papers and are essentially the same. Examples of reactor noise from both the Calder Hall reactor and Dido are given in Figs. 1 and 2. The results show that the root mean square noise power in the Calder Hall reactor for all frequencies above 0·001 c/s is 0·13%. In comparison, the noise power of Dido for frequencies above 0·02 c/s is 0·5% root mean square. The higher value of the noise in Dido is due to small movements of signal arm members which were subsequently strengthened.

US REACTOR PROGRAMME

A report of the US ten-year nuclear programme was given in NUCLEAR POWER, April 1960, p. 140 and Part IV, 'Plans for development as of February 1960' TID-8519 reviewed then, has now been published. The following technical status reports as of 1959 (Part III) have also been received: fast reactors TID-8518 (1); heavy water moderated reactors TID-8518 (4); boiling water reactor technology TID-8518 (5); sodium graphite reactors TID-8516 (6); organic-cooled power reactors TID-8518 (7).

BWR DYNAMIC BEHAVIOUR

The characteristics of boiling water reactors are sensitive to pressure variations at atmospheric pressure due to the dependence of saturation temperature on pressure. The two most important effects are the change of hydrostatic pressure within the core, leading to a change of saturation temperature with position, and pressure variations due to the acceleration of water by changing steam volume.

A system of equations is derived in a paper 'The influence of pressure on boiling water reactor dynamic behaviour at atmospheric pressure' by Joseph A. Fleck, Jr, of the Lawrence Radiation Laboratory, University of California, taking into account these pressure effects in a natural circulation boiling water reactor. Sample calculations reveal no special tendency toward instability other than a form of hydraulic instability which does not depend on the inclusion of pressure effects in the model.

MULTIPLE CORE BEHAVIOUR

Early predictions indicated that the Dresden reactor, when cold, could be made to behave as several, loosely-coupled critical assemblies. An experiment designed to demonstrate this is described in a paper 'Multiple core behaviour of the Dresden reactor' by A. S. Barta and R. O. Brugge of the General Electric Company, Power Equipment Department. Its main purpose was to show that the reactor has more than one characteristic mode of operation and that a flux measurement on one side of the core does not necessarily mean that it is the same on the other. These extreme flux distributions are part of a special test and in no way resemble the normal operation of the reactor.

FLUIDIZED BED REACTOR

A paper by Martin R. Schere of the Martin Company entitled the 'Liquid fluidized bed reactor program' states that the attractiveness of the concept is due to three major features: the small particles and semi-fluid state of the fuel; the confinement of the fuel pellets in the core region; and the possibility of using unclad UO_2 fuel pellets.

The paper describes in detail the present state of LFBR studies and the potential advantages and disadvantages of the system.

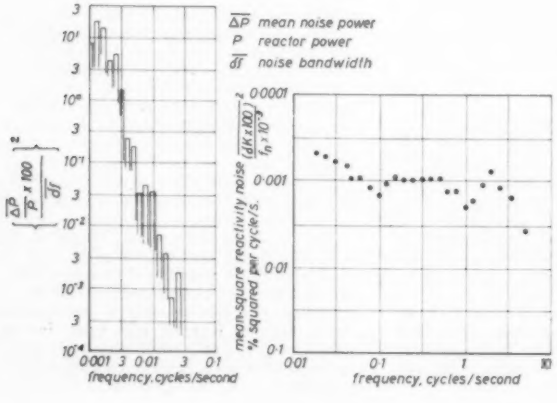

$\overline{\Delta P}$ mean noise power
P reactor power
$\overline{df}$ noise bandwidth
$\frac{\overline{\Delta P}}{P} \times 100 \sqrt{\frac{df}{f_n}}$
mean-square reactivity noise $\frac{(dk \times 100)^2}{f_n \cdot 10^{-3}}$
% squared per cycle/s.
frequency, cycles/second
frequency, cycles/second

Fig. 1 (left) Noise power in a Calder Hall reactor due to all reactor effects

Fig. 2 (right) Power spectrum of Dido net reactivity noise

New Reports

The deposition of strontium-89 and strontium-90 on agricultural land and their entry into milk after the reactor accident at Windscale in October 1957. F. B. Ellis, H. Howells, R. S. Russell and W. L. Templeton. AERE Harwell. *Report AHSB (RP) R2.* 31 pp. Available from HMSO 5*s*.

Selected reactors of the power reactor demonstration program. A 34-p literature search compiled by James M. Jacobs. USAEC June 1960. *Report TID-3556.* Available from OTS $0·75 or depository library.

Nomogram for the preliminary sizing of boiling water reactor pressure vessels. Emil L. Martinec. Argonne National Laboratory. Paper read to the Sixth Annual Meeting to the American Nuclear Society. For copies apply to the author.

The community impact of peaceful applications of atomic energy. Based on a study made by the American Municipal Association under contract with the AEC. March 1960. *Report TID-8202.* 80 pp. Available from OTS $1·00 or depository library.

A fast neutron counter for dosimetry. A more complete description of a simply constructed fast neutron counter described in AERE R2149. J. A. Dennis and W. R. Loosemore. AERE Harwell. *Report AERE R3302.* 19 pp. Available from HMSO 3*s* 6*d*.

Methods of calculating U-235 outputs and charges by use of ideal cascade theory. USAEC July 1960. *Report TID-8522.* 38 pp. Available from OTS $0·50.

Cross Section by GRACCHUS

THE PACE SEEMS to be stepping up in India. Enquiries about the building of her first civil nuclear power station have now come from Canada and Japan. Apart from the USSR, this makes a total of five countries showing an interest in this station—the other three are the United States, France and Britain.

The Canadians have a foot in the door through their part in the building of the Trombay research reactor. But this advantage may well be cancelled out if the controversy over the reported delays in the building of the station continues for much longer. What is surprising in the keen Japanese interest. Already, a team from the First Atomic Power Industry Group has visited India to look into possibilities. They have now apparently followed this up with a positive enquiry.

Fuji Electric Manufacturing Co., who are a member of this Group, have, I understand, an agreement with the GEC. This covers a seven-year period and gives Fuji the exclusive licence to use GEC patents in the reactor field, in Japan, Korea, Taiwan and China and non-exclusive rights in such countries as Burma, the Philippines and India. We may well see a joint GEC-Japanese company operating in India, should the GEC get the contract.

LAST MONTH I did touch upon the possibility of a fall in the price of uranium that the AEA is supplying to customers. I now hear that the basis for fuel costs for stations coming into operation after 1964 is £14,000 a ton and that the buy-back price for spent fuel is reckoned at £4000 a ton. This compares with the credit of £5000 that the AEA previously gave after the fuel elements had had an exposure of some 3000 MWd/t. A higher buy-back price is, however, paid for spent fuel if the fuel elements have not lived up to their expected life-time.

APPARENTLY that Harwell van was not the only item 'lost' by the AEA last month. A television camera should have been sent to Stockholm for display at the official stand at the Fifth International Instruments and Measurements Conference. It was only after a call from Stockholm that it was discovered that no camera had been sent. A search revealed one available at Calder Hall—unfortunately it had the slight disadvantage of being contaminated. Chapelcross couldn't spare one, as a shutdown was due. So the British genius for compromise was called upon. The result? A very large photograph of a TV camera was sent to our man in Stockholm.

PERHAPS THERE will even be this sort of compromise over the design of fuel elements for some of our civil power stations. The 'flutter', caused by streams of cooling gas, is resulting in some concern and I now hear that at long last, aerodynamicists have been called in to have a look at the designs. The flutter could, I suggest (not too seriously), be stopped by jamming the fuel elements on spikes. Eventually, of course, we may reach the exalted stage of having standardized fuel elements.

I SEE THAT this month's *Worldview* carries the news that English Electric has received the CEGB questionnaire for the Sizewell station. As the story observes, this most certainly means that they are likely to get the contract for this station. Though in theory there is nothing to prevent the CEGB from asking for more details from more than one of the tenderers, only one questionnaire was issued for each the last two stations and the contract followed.

This questionnaire is not one of the 'yes no' variety but is fairly exacting, requiring considerable documentation on points the CEGB would like clarified. And if all goes well for English Electric, this will be their first successful contract since Hinkley Point. It will be interesting to see in which direction their design teams have moved since then.

AT ONE TIME it was confidently predicted that Oldbury would be an AGR station. Now, not only is it established that Oldbury will use Magnox canning (see June issue, page 87) but I hear that the station after this will also use the same type. This may well be at Wylfa Head in North Wales where the CEGB are soon to apply for planning permission. Though the AEA is making strenuous efforts on its AGR programme, it has not apparently succeeded in making it look attractive enough for the CEGB to contemplate placing an order yet.

I CANNOT PRETEND to analyse the reasons for Mr. Vyacheslav M. Molotov being appointed Resident Representative of the USSR to the International Atomic Energy Agency. But I certainly think he will find the surroundings in Vienna an improvement on those on the fringe of Russia. He had been, since his defeat in 1957 after the death of Stalin, tucked away from the main political arena, in Ulan Bator as Soviet Ambassador to the Mongolian People's Republic. Mr. Molotov, who looks remarkably well is, no doubt, remembered most for his exercise of the 'veto' when he was the Russian Foreign Minister and delegate to the United Nations. I will be watching his work at the IAEA with keen interest.

THE DYING GASP of summer, frustratingly going out in a blaze of warmth, reminds me of Mark Twain's comment that nobody was doing anything about the weather. This has now taken a nuclear twist; the USAEC's Office of Isotope Development has placed a contract with Tracerlab to develop a nuclear weather detector. This uses a radiochemical compound to determine the atmosphere's ozone concentration, giving meteorologists an easier method of predicting weather patterns.

I hope this will be successful. My trust in weather forecasters has been sadly shaken this year as two colds and two suits that needed to be sent to the cleaners after a drenching will bear out.

On Record

'While I have no access to secret information, I have a strong feeling that we are closer than we think to the nuclear-powered aircraft, which may well give us new perimeters and possibilities.'

Sir William Hildred in his presidential report to the International Air Transport Association meeting in Copenhagen.

New Product Survey

EQUIPMENT · INSTRUMENTS · MATERIALS

★ *For further information on any item, circle the appropriate number on the reply card facing page 147.*

SHUT-DOWN AMPLIFIER

indicates excess temperature

Originally designed for Calder Hall, Bailey Meters' latest version of their transistorized trip margin indicator, the series II, is an on/off temperature trip amplifier that gives visual indication of the temperature over a pre-set range prior to the set-point. An early warning alarm is also incorporated.

The thermocouple signal is compared with a reference voltage, which may be set to an accuracy of 0·1% of the instrument range. The difference signal is passed to a h.f. chopper which converts d.c. voltage to a.c. The latter is then amplified to feed the circuits controlling the indicator and both alarm relays.

Trip-point range is standard at 0–30 mV and the on-off differential is given as less than 30 μV, independent of trip dial setting. The linear indicating scale is calibrated 0–60°C or 0–100°C and has a stability of less than 2% deflexion over a temperature change of 20–50°C. A calibrated front panel control allows the alarm point to be set anywhere in the indicated range.

★ 208

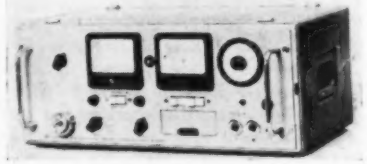
SELECTIVE MICROVOLTMETER

automatic tuning

Aveley have introduced a new automatically-tuned selective microvoltmeter for VHF range operating over a frequency of 30–400 Mc/s. Designed by Rohde and Schwarz, the 'Selektomat', type USWV, is a measuring superheterodyne receiver with an electrically tuned local oscillator.

The frequency range of 30–400 Mc/s is sub-divided into seven ranges, and tuning can be carried out manually or automatically, the automatic tracking circuits locking onto the selected frequency which is fed into the input.

The minimum input is 10 μV r.m.s., frequency response is 0·2% per Mc ± 1 dB, and input attenuation 0–60 dB. The bandwidth is 125 kc/s (3 dB down) and 1 Mc (80 dB down). The logarithmic indication is 0–80 dB and the linear indication, 0–20 dB with the additional 60 dB attenuator.



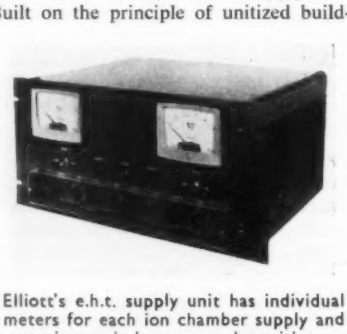
The 'Selektomat' automatic microvoltmeter can be used for frequency response measurement on 2 or 4-terminal networks

★ 209

ION CHAMBERS

stabilized power supply

For polarizing gamma compensated ion chambers, Elliott Nucleonics have introduced the ND1671, an e.h.t. supply unit. Built on the principle of unitized building blocks, each employing transistor circuits, the unit provides two separate independently variable pairs of supplies.



Elliott's e.h.t. supply unit has individual meters for each ion chamber supply and reversing switches to read positive or negative supply values

For the positive supply, with a maximum current of 1 mA, the ranges are 60–125 V, 125–250 V, 250–500 V and 500–1000 V. For negative supply, with a maximum current of 100 μA, the ranges are 10–50 V, 50–100 V, 150–200 V, and 200–250 V. Each pair is equipped with its own monitoring meter and e.h.t. failure alarm. Both positive and negative supplies are obtained from the same blocking oscillator.

★ 210

THERMAL INSULATION

new magnesia compound

Chemical and Insulating is now producing an improved type of magnesium carbonate insulating material known as Supermag. It has already been used on the heat exchange unit ducting and distributing pipes of the Bradwell station. Supermag consists of magnesium carbonate trihydrate and asbestos in the usual proportions, 85%–15%, but the manufacturing process binds the magnesium carbonate with the asbestos at a critical temperature. The material is available in pre-formed sections and slabs and is harder and stronger than orthodox magnesia products; it is also resistant to water.

★ 211

RESISTANCE WELDING CONTROL

synchronous timing

Suitable for spot welding machines up to 15 kVA, 440 V supplies, the new electronic control equipment, series FCT3, produced by Lancashire Dynamo, is designed to provide accurate synchronous timing from ½ to 5½ cycles in half-cycle steps, with a full range of stepless heat control.

An electronic contactor is incorporated for switching the welding transformer primary circuits; and transformer saturation cannot occur even when the unit is timing odd numbers of half-cycles. Heat control facilities provide for a 30:1 range of power control without tap changing, and the required heat can be adjusted to very close limits.

For controlling the largest sizes of welding machine, an alternative type of equipment is available with synchronous timing in two ranges: ½ to 5½ cycles and 1 to 11 cycles.

★ 212

WATER PURIFICATION

portable unit

The Mark 6 Portable 'Deminrolit', designed by Permutit, can convert up to 12 gal/h of clean cold water into demineralized water having a conductivity of less than 1·0 reciprocal megohm per centimetre.

Basically a mixed bed ion exchanger, it uses 'Zeo-Karb 225' and 'De-Acidite

The portable 'Deminrolit' has a capacity of 12 gallons per hour

FF'. A conductivity tester is fitted which continuously monitors treated water quality.

★ 213

RATEMETER-SPECTROMETER

single channel combination

A new instrument from Tracerlab, SC80, designed as a combined single channel ratemeter-spectrometer, incorporates a stable high voltage power supply, a linear amplifier, a pulse height analyser and a precision ratemeter. A four-speed threshold drive for automatic spectrum scanning can also be provided as an optional extra.

The ratemeter features nine ranges up to 1,000,000 counts/min with a choice of four time constants (0·5; 2·5; 10 and 40 seconds) to provide optimum response time. A new type of aural indicator facilitates tuning of the spectrometer by emitting a tone with a frequency proportional to the count rate. Conventional click-type indication is also provided.

The spectrometer incorporates an adjustable window with a maximum width of 100 V; threshold can also be varied over the same range. Both threshold and window controls are 1000 division odometer-type potentiometers which permit direct reading of control settings for continuous spectrum scanning. A synchronous drive motor can be attached to the threshold control and is supplied with four quick-change gears which permit selection of scanning times of 5, 15, 30 or 60 min.

★ 214

RADIOACTIVE SAMPLING

centrifugal preparation

Recently introduced by Atomic Products, the Atomlab-Ekstein tube centrifuges radioactive precipitates directly on to standard 1·25 in. diameter sample pans, without loss of activity.

In use, a standard planchet is placed in position at the bottom of the liner and is held there by an 'O' ring seal. This liner is then slipped into the outer cup, filled and centrifuged. The supernatant liquid is then decanted and the planchet removed for counting.

The number of tubes that can be spun simultaneously is limited only by the capacity of the trunnion carrier.

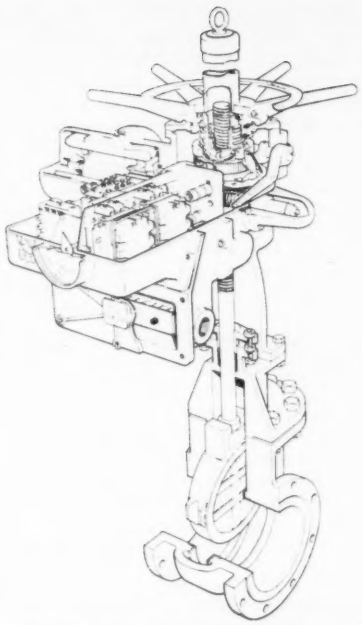
★ 215

MOTORIZED VALVES

variable speed actuator

Rotorks have developed an actuator for motorized valve movement that allows starting and stopping at any point. An electrical control scheme provides transmitters for remote positioning.

The machine is powered by a 3-phase



Rotork actuators allow automatic and remote control valve operation. They are also being made under licence in France, Italy and Germany

AEI squirrel cage electric motor and, using variable speed mechanism, sudden closing or opening of valves is avoided. The motor is controlled through appropriate contactor coil circuits by open limit and closing torque switches, with appropriate combinations to suit various valve requirements.

For valves requiring high torque at low speeds, secondary stage reduction gears can be incorporated. Auxiliary switches permit lamp indication of valve positioning, interlocking, etc.

The hollow output shaft with a removable drive unit enables the actuator to be mounted directly on to the valve yoke or gearbox to form a compact and rigid unit.

★ 216

NEUTRON PULSE RATE METER

wide range count

A logarithmic count rate meter, which measures neutron pulse rate and reactor period during start-up range operation, is now available from International General Electric. With a wide six-decade scale, pulses from 10 to 10 million counts/m can be measured without changing range and with equal accuracy.

The wide range of count rate and complete lack of zero drift is made possible by the use of the passive networks which perform the logarithmic function. The instrument computes the log of the average arrival rate of neutron pulses and displays the count rate on a logarithmic meter; signal output is also available for remote meter and recorder connexions. It may also be used with a pulse preamplifier or connected directly to a primary detector having a strong signal.

During start-up, flux level is indicated by neutron pulse rate. The period meter has a range of − 30 to infinity to + 3 sec and, in connexion with a lock-type alarm device, is used for instantaneous protective circuit trip and shut-down.

Apart from reactor use, with scintillation counters, the meter can be used for laboratory analyses and for continuous beta or gamma monitoring.

★ 217

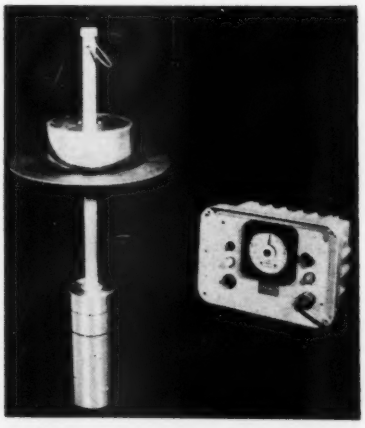
The GE log count rate meter with period provides continuous indication and instantaneous trip for reactor start-up operation

RADIATION MONITORING

liquid milk contamination

A transistorized radiation monitor, designed specifically for measuring the level of radioactive contamination in bulk quantities of milk, has now been added to the range of standard and special purpose monitors made by Plessey Nucleonics.

The new equipment, consisting of a detector probe and an indicator unit operated from a 12 V car battery or a.c. mains, is designed for use with standard 10-gal milk churns, the indicator unit operating when the probe is lowered into a churn.



The indicator unit of the Plessey milk monitor is calibrated for infant tolerance and has two ranges either side of a centre zero meter

A thin-walled geiger müller tube detects both beta and gamma radiations and the count rate is presented on an indicator calibrated directly in terms of tolerance levels.

By providing the indicator unit with a centre zero meter whose pointer is deflected in opposite directions for the two ranges provided, the chance of ambiguous readings is removed and allows the equipment to be used by unskilled personnel.

The unit is housed in a watertight container so that it can be installed permanently in dairy yards.

★ 218

DATA AMPLIFIER

transistorized unit

To meet the need for the precision amplification of microvolt output signals from transducers in instrumentation and control systems, Blackburn Electronics have developed a transistorized Data Amplifier.

The input, which is completely floating, has a common mode rejection ratio of 10^6:1 at DC, and an impedance of 3 M Ohm which ensures that the unit will not load the signal source. The total noise and drift in the amplifier is below 5 μV r.m.s., with a rise time of 10 m/sec.

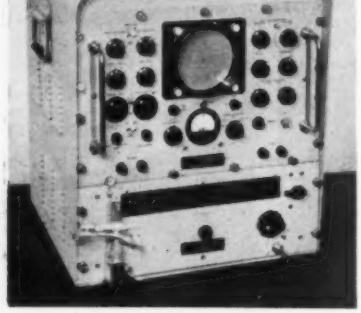
The gain of the unit is switchable from 10 to 1000, and it has a linearity of 0·1% with a maximum output swing of ± 10 V at 0·5 amp.

★ 219

SPECTRUM ANALYSER

wide frequency range

Designed for wide band frequency analysis, the Spectrum Analyser Type LA20, manufactured by Lavoie (distributed by Metrix), is a self-contained instrument with an operating range of 1000–4400 Mc/s. The wide range is obtained by the use of detachable waveguide mixers above the basic range of 16,000 Mc/s and, over the whole frequency band, a resolution of 10 kc/s is possible.



The new Lavoie wide band spectrum analyser has a range of 1000–4400 Mc/s

The circuit design is such that the sensitivity of the instrument is constant, resulting, in a good flat response. The frequency dispersion is adjustable between 500 kc/s and 70 Mc/s, and linear, square law or logarithmic detection and display can be selected. Calibration is provided by a ± 35 Mc/s marker; other refinements include a 0–60 dB step attenuator in the IF stage, a rise and fall trace intensifier with baseline extinction, stabilized filament and H.T. supplies, and provision for camera mounting.

Alternative models covering the band 10 Mc/s to 44,000 Mc/s are also available.

★ 220

IN BRIEF

Linear potentiometer. From the newly formed Miles Electronics division comes the MCD 30/FG, a linear potentiometer with two-end connexions and 33 intermediate taps. 3 in. in diameter, it has been designed as a function generator and, by shunting sections of the winding with suitable resistors, a wide range of non-linear outputs can be obtained.

★ 221

Transmission clutch. An addition to Metaducts' power transmission equipment, a small overload slipping clutch, has been designed for use on motor driven rotary transformers to give unattended automatic voltage regulation.

★ 222

Liquid metal valves. Deloro Stellite alloys are being used for the protection of valve components where high temperature, high hardness, high strength and low rate of corrosion are specified. Components can be Stellite welded or sprayed, or supplied cast and ground.

★ 223

Plastic lead. Devcon L, a combination of some 94% lead and 6% special thermo-setting plastic, can be moulded easily to shape and hardens after three hours to a malleable form. Shrinkage during hardening is never more than 0·0005 per in. Foley-Breckley, the makers, claim excellent adherence to lead, aluminium, concrete, cast-iron, etc.

★ 224

Fast counters. Telephone Manufacturing Co. have introduced a range of Elmeg counters in printout and readout form, with operating speeds of up to 40 impulses/sec. They can be reset by electrical, mechanical or electro-mechanical methods.

★ 225

Radiographic inspection. Rigaku-Denki of Tokyo have developed a range of X-ray radiography units for the inspection of welds, castings and other assemblies. Output varies from 125 kVP, 5 mA, to 250 kVP, 5 mA, with a penetration of from 37 mm to 85 mm respectively. The Radioflex 160 model is a portable type weighing 48 lb.

★ 226

Miniature a.c. motors. For applications such as programmers, long-life repeat cycle time and time delay relays, etc., a 60-cycle timing motor, weighing 5 oz, is available from Haydens. With a length of $\frac{7}{8}$ in., it is available in the voltage range 6-230 V, 20 mA max., with rotor speed of 300 rev/min.

★ 227

Pneumatic cylinders. Martonair's recent range of $\frac{1}{4}$ in. diameter double-acting pneumatic cylinders is available in three stock lengths of stroke: 1 in., 2 in. and 4 in.

★ 228

Low refractive windows. Semi-Elements are now producing a new window material, made from single sodium fluoride crystals. It is suitable for applications where a very low refractive index is needed, such as windows in ultra-violet and infra-red radiation detection systems.

★ 229

Flexible couplings. The Quadriflex coupling developed by R. and J. Dick, consisting of two flanges and a two-piece flexible rubber sleeve, provides for angular misalignment up to 1°, parallel misalignment up to $\frac{1}{16}$ in. (depending upon shaft size), and free-end float up to $\frac{1}{8}$ in. (depending upon coupling size).

★ 230

Auxiliary motors. A new series of Westinghouse motors, ranging from 40 to 250 h.p., is available in three basic designs: for normal torque, high breakaway torque, and for high accelerating duty or high inertia loads.

★ 231

Burner control. Honeywell's 'Purple Peeper,' designed for flame control in industrial burners, uses an ultra-violet sensing unit which gives a flame response time of less than 0·1 sec.

★ 232

STUDENTS' NOTEBOOK

GROUNDWORK—Information

What sources are available on Russian progress in science and technology?

We are constantly reminded of the growing volume of literature that reports progress in science and technology. As we pointed out in an earlier article (May 1960, page 109), very good abstract services exist that guide the student through the mass of articles and reports, including those written in foreign languages.

Until recently, however, it has been difficult to find out what progress is being made in the USSR. It has not been easy to acquire copies of current Soviet publications, let alone obtain English translations. Fortunately, this problem has received the urgent attention of the Department of Scientific and Industrial Research. By purchase, and with the cooperation of many organizations in this country and abroad, the Lending Library Unit, LLU, of DSIR has built up a collection of recent Russian scientific and technological literature, the largest in Western Europe.

Apart from two lists:—'Titles of periodicals from the USSR and "cover-to-cover" translations', and 'List of irregular serials received from E. Europe and the USSR', the LLU publishes a monthly 'LLU Translations Bulletin', obtainable at 4s from HM Stationery Office. In addition to listing individual translations available for loan, the latest Russian journals received as cover-to-cover translations, and books in the process of being translated, the Bulletin includes full length articles in English on various aspects of Soviet technological progress.

The LLU sponsors the regular cover-to-cover translations of 15 important scientific periodicals and makes available for loan almost 200 other similar translations (including abstracts journals) which are produced elsewhere, mainly in the US. Consequently it is now possible to borrow the important publications of the Academy of Sciences, such as those that cover chemistry, physics, chemical technology and applied physics; journals on automation, metal physics, measurement techniques, metallurgy, automatic welding, welding production, and many others.

The Soviet 'Journal of Atomic Energy', translated both by the Consultants Bureau in the US, and by the Pergamon Press in the UK, is also available. In the latter case, it is incorporated in the 'Journal of Nuclear Energy' Part A.

15,000 separate article translations are possessed by the LLU, a number that includes microfilm copies of those held by the Special Libraries Association of America. Current SLA accessions are listed in 'Technical Translations', issued by the Office of Technical Services, Washington (£6 6s per annum through HMSO). Subjects covered include chemistry, engineering, materials, mathematics (and computers), metallurgy, nuclear physics and chemistry and nuclear power.

A useful guide to the contents of current Russian periodicals on science and technology is included in the 'Monthly index of Russian accessions', issued by the US Library of Congress ($16 per annum). A similar compilation, the Monthly Translation Service, is issued by the Consultants Bureau ($25 per annum). This, however, serves as a guide to Soviet journals currently being translated into English by the Bureau.

Organizations who wish to borrow translations from the LLU must first be accepted by the Science Museum Library, London, SW7, and then use the loan requisition forms issued by that library.

NEWSBRIEFS

- Cornell University is to have a 10 kW Triga reactor; probable date of completion is September 1961. Another 10 kW reactor, from Allis-Chalmers, is to go up at Maryland University. The USAEC is making a $150,000 grant in both cases.
- To get small firms to step-up their drive for technological progress, the FBI have arranged a three-day conference this month for top executives of such firms, with the purpose of examining recruitment and training problems.
- John Thompsons is one of the British firms that receives overseas students for systematic training in industrial techniques. Students currently studying at the Ettingshall works include a technical instructor from La Paz University in Bolivia, a graduate from Alexandria University and two Spanish students.
- Southampton University is to receive a grant of over £2000 per annum for three years to provide for a Research Studentship and a Research Fellowship in synthetic organic chemicals. Union Carbide are making the grant to encourage and advance research in this field of chemistry.
- In 1959, of the 119 candidates who took the Graduateship examination of the Institute of Physics, only 39 passed.
- Ultra Electronics have awarded three 2-year research scholarships. Starting this Autumn, research will be undertaken by the selected students—at King's College on microscopic measurement, at Nottingham University on computer systems using ternary devices, and at University College, London, on electronic means of producing synthetic speech.
- Wisconsin University is to be issued a permit to construct a US General Electric 10 kW pool-type reactor; completion is expected by late 1960.

UK COURSES

Hawker Siddeley Nuclear Power Co. Ltd. Reactor operation courses on the 'Jason' reactor. Basic course on routine operation—total duration optional. Fee: £5 5s per day. Advanced course for reactor experiments—3–5 weeks. Fee: £15 15s/day.

Lanchester College of Technology, Coventry Nuclear engineering—14 lectures, Wednesday evening: November to February. Fee: £1 12s.

Northampton College of Advanced Technology, London Theory of structures for mechanical engineers—23 lectures, Friday evenings, commencing October 7, Fee: £3 3s. Mechanics of metals—20 weeks, Mondays, commencing October 10. Fee: £4 4s. Advanced strength of materials—20 weeks, Thursdays, commencing October 6. Fee: £4 4s. Creep and the use of Metals at high temperatures—11 lectures, Tuesday evenings, commencing October 4. Fee: £3 3s. Experimental strain analysis—20 weeks, Thursday evenings, commencing October 6. Fee: £5 5s.

Manchester College of Science and Technology Fatigue of metals — September 28–29. Fee: £7 10s. Problems of radioactivity at Water and Sewage works—September 29–30. Fee: £7.

Council of Industrial Design, London Design appreciation course for apprentices and junior engineers from light and heavy engineering industries — two residential periods, each of four days, separated by an individual study period of three weeks. Fee: 35 guineas. Further information from the Council.

- Trade union officials are to attend a four-day course this month, at Wantage, on the industrial uses of radioisotopes. Special attention will be given to health and safety.

HARWELL'S NEW LIBRARY Opened this month, it houses a stock of some 20,000 volumes of books and periodicals, 250,000 technical reports, 50,000 microcards and 27,000 pamphlets. The Reading Room covers 6000 square feet and will accommodate 21,000 volumes. Rate of expansion is at about 4000 volumes and 30,000 reports each year

BUSINESS NEWS

HAWKER SIDDELEY SPREAD WINGS After some months of negotiation, the *Hawker Siddeley Nuclear Power Co. Ltd.* has acquired *Nuclear Engineering Ltd* of Greenwich, a former subsidiary of *G. A. Harvey & Co. (London) Ltd*. The Greenwich firm has been making equipment for handling and using radioactive isotopes. It will now concentrate on irradiation equipment. Its activities in the medical therapy and industrial radiography field have been taken over respectively by *Test Equipment (Models) Ltd* of Sussex and *Pantatron Ltd* of London.

TRIGA USES BRITISH COMPONENTS The delivery of 22 reactor control ionization chambers for incorporation in the control systems of Triga reactors being built by *General Atomics* of the US has been completed by *20th Century Electronics Ltd of Croydon*. The order included 20th Century's type RC6, a gamma compensated ionization chamber based on AERE designs.

ELLIOTT - LEYBOLD TIE-UP *Elliott Brothers (London) Ltd* and *Leybold's of Cologne* have formed a joint company, *Leybold-Elliott Ltd*, to exploit throughout the Commonwealth, except Canada, the industrial vacuum process equipment of both parent companies. Elliott's have a majority interest in the new firm which will later extend the range of products to be marketed still further. By a reciprocal agreement, these products and those of Elliott's may be marketed in certain European countries by the Leybold group of companies.

JOHN THOMPSON BUILDS INDIAN PLANT *John Thompson Ltd* have signed an agreement with the *Indian Sugar and General Engineering Corporation* to build a new plant in the Punjab capable of handling the fabrication of Berkeley or Dungeness type heat exchangers (see *Progress in Industry*, this issue).

UK COMPUTER FOR ITALY *Miles Electronics* have received two further orders for analogue computing equipment for nuclear reactor applications in Italy and Norway. One installation has been ordered for Rome University by the *Comitato Nazionale per le Ricerche Nucleari*, mainly for training purposes; the other is for the Kjeller Research Establishment where it will be used in conjunction with a general purpose computer.

COMPUTER FOR HIRE A computing service, based on a machine using both analogue and digital techniques, is being operated at the Computer Department of *Redifon Ltd*, Crawley. The machine on hire is the Radic (Redifon Analogue-Digital Computing System) and it is available at £12–£50 an hour, depending on the size of the computation. It is intended to transfer the service centre to the inner London area and extend the capacity of the present equipment.

CHANNEL CABLE CONTRACT AWARD *AEI Ltd* and *British Insulated Callender's Cables Ltd* have been awarded a £610,000 contract for cross-Channel power cables by the CEGB. The two firms will lay half the cross-Channel submarine cable link which will connect the British and French electricity systems. The other half will be laid by French companies.

WINDSCALE ORDER FOR PLESSEY All the nuclear instrumentation for the advanced gas-cooled reactor at Windscale is to be supplied by *Plessey Nucleonics Ltd*. The complete instrumentation assembly consists mainly of standard equipment currently in production. Plessey are also supplying the Ministry of Agriculture, Fisheries and Food with a number of their recently developed milk monitors and also with their food contamination monitors.

NASH & THOMPSON LTD, Surbiton, a member of the *Thorn Electrical Industries* Group, are making and marketing an industrial closed-circuit TV unit. Cost of the camera is said to be £275. A control unit is not needed.

NEW HEADQUARTERS The new head offices of the English Electric Group of companies in the Strand which were officially opened recently

PRINTED CIRCUITS LTD. in association with *Millet Levens Ltd*, have opened a new automatic factory at Borehamwood, Herts, for the production of all types of printed circuits.

JOHNSON, MATTHEY & CO. LTD. are now producing very pure arsenic, antimony, tellurium and bismuth on a commercial scale.

GRESHAM DEVELOPMENTS LTD. and *Lion Electronic Developments Ltd.* have amalgamated to form a new company, *Gresham-Lion Electronics Ltd.*

OVERSEAS

NEW FRANCO-US FIRM A new Franco-US company to study, design and install electronic equipment for data processing and automation of industrial and scientific process in the Common Market countries has been formed in Paris. The parent companies are *Compagnie Générale de Télégraphie Sans-Fil, Société Intertechnique* of Paris, and *Thompson Ramo Wooldridge Inc.* of Los Angeles.

GERMAN HEAT-EXCHANGER TALKS *Rekuperator K-G* of Düsseldorf are negotiating with the *Technische Hochschule*, Hanover, on the design of a heat exchanger for a marine reactor. Rekuperator is also carrying out similar negotiations with *Interatom* for a heat exchanger for an organically moderated reactor.

SCANDINAVIAN AGENTS FOR NUMEC *Nuclear Materials & Equipment Corp.* (Numec) of Pennsylvania has appointed *A. Johnson & Co.* of Stockholm as its representative in Sweden, Denmark, Norway and Finland. Similar arrangements covering other areas in Europe and Asia are being negotiated.

CANADIAN FUEL FOR JAPAN *AMF Atomics Canada Ltd* is to manufacture 270 natural uranium fuel elements for use in the Japanese JRR-3, 10 MW heavy water moderated research reactor. This will be Canada's first private export sale of fuel elements. Shipment is to be completed by the end of the year.

ISOTOPE LAB FOR OAK RIDGE A new *Radioisotope Development Laboratory* is to be built for just under $M1 at the AEC's *Oak Ridge National Laboratory*. It will be completed in about a year and will help in producing a wider variety of radioisotopes.

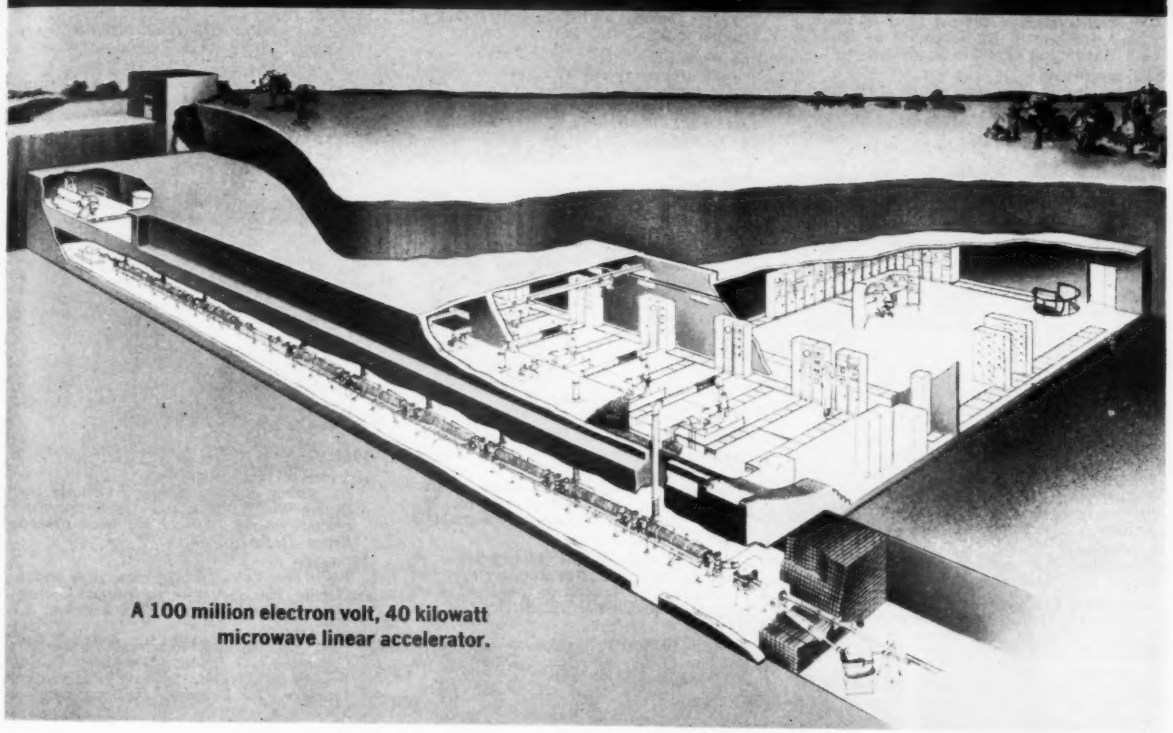
MAGNETIC COIL CO. of Ontario's new address is 12 Laurel Street East, Waterloo, Ontario.

FAIRBANKS-MORSE & CO. of the US has established an electronics division which will, among other activities, co-ordinate the marketing of products made by *EMI Electronics Ltd, London.*

AMF OF THE US has formed a new subsidiary, *AMF Maschinen GmbH*, to handle its increasing business in Austria.

SETTING NEW STANDARDS

at 99.98% of the speed of light.



A 100 million electron volt, 40 kilowatt microwave linear accelerator.

One of the world's most powerful when completed, this high-energy electron accelerator will enable the U. S. National Bureau of Standards to carry out extensive programs in:

- Nuclear Physics Research
- Radiation Effects
- Dosimetry Standards

. . . to meet the need for new data in the growing field of applied radiation.

The linear accelerator (Linac) is under construction at the manufacturing and test facility of Applied Radiation Corporation, Walnut Creek, California.

Particle accelerators for science and industry.

HIGH VOLTAGE SERVICING CO., LTD.,
60 Carpenters Wood Dr.,
Chorley Wood, Herts.
Telephone: Field End 7431

HIGH VOLTAGE ENGINEERING CORPORATION
BURLINGTON, MASSACHUSETTS • U. S. A.
APPLIED RADIATION CORPORATION — HIGH VOLTAGE ENGINEERING (EUROPA) N.V.

Circle No 65 on reply card for further details

Diary

25–28 SEPTEMBER
American Institute of Chemical Engineers Meeting on *corrosion of construction materials and chemical reactions induced or modified by ionizing radiation, Tulsa*

26–30 SEPTEMBER
15th Annual *Instrument-Automation* Conference and Exhibit, New York. Details, Instrument Society of America, 313 Sixth Avenue, Pittsburgh 22, Pa, USA

27 SEPTEMBER
The Maintenance Problems in a Nuclear Power Station: J. R. Treharne, at Sheffield, Institution of Plant Engineers

27–28 SEPTEMBER
Symposium on *Automatic Control* (British contribution to IFAC congress), London. Details, Institution of Mechanical Engineers, London, SW1

27–30 SEPTEMBER
Power Systems Conference, American Rocket Society, Santa Monica, California. Details, Roderick L. Hole, American Rocket Society, 500 Fifth Avenue, New York 36

27 SEPTEMBER—1 OCTOBER
The Physics of Electrostatic Forces and their Applications, International Meeting, Grenôble, France. Details, Prof. N. J. Felici, Institut Fourier, Place Doyen-Gosse, Grenôble, (Isère)

29 SEPTEMBER
The Extraction of Metals and the Chemistry of Metals, Fourth Robert Horne Memorial Lecture, by Prof. F. D. Richardson, University of Bristol. Details, Society of Chemical Industry, London, SW1

29–30 SEPTEMBER
International symposium on powders in industry, London. Details, Secretary, Surface Activity Group, Society of Chemical Industry, 14 Belgrave Sq., London, SW1

2–5 OCTOBER
European Federation of Chemical Engineering, 28th annual meeting. Mannheim

Verfahrens-Ingenieure annual meeting, Mannheim. Organized by Process Engineering Group of Association of German Engineers, Frankfurt/Main

3–5 OCTOBER
Seventh Annual Meeting, Professional Group on Nuclear Science, Institute of Radio Engineers, Oak Ridge, Tennessee

3–7 OCTOBER
Fifth International Atomic Energy Seminar, Wiesbaden, Germany. Details, Mr Trebst, Internationale Studiengesellschaft e.V., Theodorenstr 6–8, Wiesbaden

4–6 OCTOBER
Accelerator Conference, Amsterdam. Details, Mr. Jan S. Woldrigh, managing director, High Voltage Engineering (Europa) NV, Amersfoort, Netherlands

6–13 OCTOBER
Fifth International seminar for sanitary engineers, inc. *Sanitary Engineering requirements of Atomic Energy*, Madrid. Details, World Health Organization, Geneva

7 OCTOBER
Sixth Castner Memorial Lecture, Glasgow, *The Fusion and Electrolysis of Titanium*, Dr W. J. Kroll of Corvallis, Oregon. Details, Society of Chemical Industry, London, SW1

10 OCTOBER
Plant Engineering on the Continent, Royal Society of Arts, London. Details, The Institution of Plant Engineers, 2 Grosvenor Gardens, London, SW1

11–13 OCTOBER
Deutsches Atomforum Conference on the *Applications of Nuclear Energy*, Karlsruhe. Details, Prof. Ing. Kupfmuller, Deutsches Atomforum, Fredrichstr, 2 III, Düsseldorf, Germany

11–14 OCTOBER
Inelastic Scattering of Neutrons in Solids and Liquids, IAEA Symposium, Vienna

12 OCTOBER
Steam for Process, University of Bristol. Joint meeting. Institutions of Heating and Ventilating, Hospital Engineers and Plant Engineers

12–14 OCTOBER
4th Conference on *Analytical Chemistry in Nuclear Reactor Technology* and 1st Conference on Nuclear Reactor Chemistry Oak Ridge National Laboratory at Gatlinburg, Tennessee

13th annual *Gaseous Electronics* conference, Monterey, California. Details, Mr. N. L. Olsen, US Naval Post-graduate School, Monterey

Modern Trends in the Manipulation of Metals, Conference, Brighton. Details, The Secretary, The Institution of Production Engineers, 10 Chesterfield Street, London, W1

Seventh National Symposium, American Vacuum Society, Cleveland. Details, AVS, Box 1282, Boston 9, Mass

17–21 OCTOBER
IAEA *Neutron Pile Research* Symposium Vienna

17–22 OCTOBER
World Health Organization Symposium on *Diagnosis and Treatment of Acute Radiation Injury*, Geneva

18–21 OCTOBER
1st *Effluent and Water Treatment* Exhibition at Seymour Hall, London, W1

19–26 OCTOBER
International Congress and Exhibition for *Instrumentation and Automation* (Interkama) Düsseldorf

21 OCTOBER
Fourth Annual Symposium on *Advances in Tracer Methodology*, Chicago. Details, R. F. Wood, Baird Atomic Inc., 33 University Road, Cambridge, Mass

24–25 OCTOBER
29th meeting, European Federation of Chemical Engineering, Barcelona

24–27 OCTOBER
IAEA *Chemical Effects on Nuclear Transformation* Symposium Prague

26–27 OCTOBER
Computer Applications symposium, Chicago. Details, Mr. A. Ungar, Armour Research, 10 W. 35th St., New York 13.

31 OCTOBER—2 NOVEMBER
13th Annual Conference on *Electrical Techniques in Medicine and Biology*, Washington. Details, Dr. Robert L. Bowman, National Heart Institute, National Institute of Health, Bethesda 14, Md, USA

Future months

14–18 NOVEMBER
IAEA *Nuclear Ship Propulsion and Safety* Symposium, Taormina, Sicily

29 NOVEMBER—2 DECEMBER
Corrosion and Metal Finishing Exhibition, Empire Hall, Olympia, London. Details, 9 Eden Street, London, NW1

1961

18 JANUARY (provisional)
Institution of Mechanical Engineers and British Welding Research Association Symposium *Pressure Vessel Research towards Better Design*, London

15 MARCH
Burst Slug Detection Symposium, London. Details, The Society of Instrument Technology, 20 Queen Anne Street, London, W1

10–15 APRIL
First International Congress on *Metallic Corrosion*, London. Details, Lt-Col. Francis J. Griffin, Society of Chemical Industry, 14 Belgrave Square, London, SW1

1962

20–26 OCTOBER
World Power Conference, sixth plenary meeting, Melbourne, Australia

Industrial Literature

Analogue computer. Working details of the centrally patched analogue computer, G-Pac Mark II, exhibited at the last IEA Exhibition, are now available in Panellit's latest publication. ★ 252

Electronic components. Ediswan's 1960-61 data booklet groups valves, cathode ray tubes and semiconductors in separate sections. Obsolescent types are listed together with replacement type and any necessary modifications. ★ 253

Nuclear instruments. Labgear's abridged catalogue is a brief illustrated guide to their range of scalers, timers, counters, discrimators and power supplies. ★ 254

Welding manipulation. Holding and positioning equipment for welding work are described in a brochure from Ross, and it covers magnetic clamps, jigs, pipe aligners, turning rolls, etc. ★ 255

Hall multiplier. The current issue of Muirhead's 'Technique' contains an article by E. Cohen on 'some measurements of intermodulation and harmonic distortion in Hall effect multipliers by means of a Muirhead-Pametrada wave analyser'. ★ 256

Steel castings. Of use to the design engineer and draughtsman is the new booklet from Brown, Lenox, that lists against various castings, specifications and properties. ★ 257

Electric furnaces. A wide variety of low- and high-temperature heat-treatment equipment for laboratory use are available from Wild Barfield, and their latest catalogue gives specifications of muffles, small furnaces and recommended ancillary equipment. ★ 258

Technical furniture. Widney Dorlec's constructional system consists of an extensive range of frame members, corners and joints made from high-duty light alloys. Details of the range and the shapes that can be evolved are given in a recent catalogue. ★ 259

Industrial valves. Two leaflets from Mullard give details of their microwave valves and of the cadmium photoconductive cells that have been developed for industrial use. ★ 260

Pressure measurement. An illustrated leaflet from Wallace and Tiernan contains brief details of, and a selection guide to, their pressure sensitive instruments. Included are gauge, vacuum and differential pressure indicators, and absolute pressure indicators. ★ 261

** For further information on any item circle the appropriate number on the reply card facing page 147.*

Here is the NEW LOOK

125 c.f.m.
"POWER VANE"
ROTARY COMPRESSOR

from Consolidated Pneumatic

A new design makes its debut . . . the dynamic 'new-look' Power Vane 125 Compressor. The canopy design has been re-styled and streamlined, and finished in two-tone green colour scheme. The unit is now considerably lighter in weight; fitted with fold-away tow-bar wheel and lifting handles for improved manoeuvrability. The new design means easier access to tool-box and engine for day-to-day maintenance; easier canopy removal for major overhauls.

The 'new-look' model retains the advantages of modern rotary design—its two-stage in-line oil-cooled unit eliminating pistons, crankshaft, clutch and valves. Electric starting is standard; regulation is fully automatic.

Robust and reliable as ever, the 'new look' Power Vane 125 Rotary Compressor now adds easier accessibility, easier maintenance, easier handling to its fine reputation for toughness.

POWER VANE

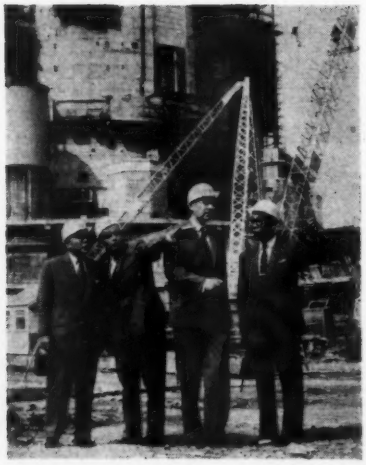
A brochure giving full details is available on request.

CONSOLIDATED PNEUMATIC TOOL CO. LTD., DAWES ROAD, LONDON S.W.6

CP243

People

by John Radford



HUNTERSTON VISIT The Japanese Ambassador in Britain, Mr K. Ohno (left), and Mr D. W. T. Angwin, GEC chief resident engineer, discuss points during Mr Ohno's recent visit to Hunterston. On their left are Mr. R. N. Millar, managing director, the GEC's engineering group, and Mr. S. Tamiya, scientific attache, Japanese Embassy

THE NEW works manager for Sir W. H. Bailey & Co. Ltd, Manchester, is to be **Commander E. G. Sutton.** In his new position, the Commander will be responsible for the production of the whole range of pressure regulators, sluice valves, pumps and turnstiles made by the company. I remember Commander Sutton when he was with the John Thompson Group and was responsible for the charge face equipment for Berkeley. Previous to this, he was chairman of the Admiralty Remote Power Control Panel.

Seven months after being appointed as general manager of Fafnir Bearing Company Ltd of Wolverhampton, **Mr G. H. Marchant** has been elected to the board of directors He will still continue as general manager of the firm, which makes graphite support bearings for the nuclear

G. H. MARCHANT
directorship

H. A. ANDREWS
settles in

industry and is one of the largest ball bearing manufacturers in the country. Prior to joining Fafnir, Mr Marchant was works manager of Fischer Bearings Co Ltd, works director of Sentinel (Shrewsbury) Ltd and general works manager of Joseph Sankey & Sons Ltd.

Settling in as the general manager of Power Auxiliaries Ltd, a company in the Plessey Group, is **Mr H. A. Andrews.** He was recently appointed to the position after 21 years' service with the Plessey Company Ltd. During this time he was successively General Manager, Plessey (N. Ireland) Ltd; general manager, Wiring and Connectors Division at Rotherham and was appointed divisional manager of the Wiring and Connectors Division at Swindon in 1958.

SIMA's Council for 1960–61 has been elected, **G. C. Ottway** of W. Ottway & Co. becoming President and the retiring President, **L. A. Woodhead** of Cossor Instruments, automatically becoming a Vice President. **A. W. Jones** of Fleming Radio is also a Vice President, **A. W. A. Rundle** of A. Gallenkamp is Hon Treasurer, and **E. R. Ponsford** of Solartron is Hon. Secretary. The new Council members are **S. T. Pickering** of Chance Pilkington, **G. M. Sisson** of Sir Howard Grubb Parsons, **G. S. Sturrock** of Kelvin & Hughes and **R. Foxwell** of Wayne Kerr Laboratories.

Sir Donald Perrot, who retired as AEA Member for Finance and Administration at the end of July, has been appointed a director and deputy chairman of Dewrance & Co. Ltd. Sir Donald told me that he took up his new job at the beginning of August. Dewrance have also made further appointments. **Mr D. Handley** has been appointed technical director at head office and **Mr M. T. Cunningham** is now chief engineer in place of **Mr J. H. Gibson** who remains on the board. The firm also announced that **Mr M. J. Verey** had resigned from the board.

Two members of the Chemistry Division of Argonne National Laboratory have started research assignments at Harwell under a staff exchange programme between the two establishments. They are **Dr Henry R. Hoekstra,** associate chemist and **Dr Herbert H. Hyman,** senior chemist. Dr Hoekstra, I understand, will study the chemistry of uranium oxide compounds with **Dr L. E. J. Roberts,** director of a research group on solid state inorganic chemistry. His colleague, Dr Hyman, will take part in fission product chemistry research with **Dr Eugen Glueckauf,** deputy chief scientist at Harwell.

Coinciding with its expansion into advanced commercial electronics is the election by the Lionel Corporation of New York of **Major General J. B. Medaris** as its president and as a director. A former chief of the US Army Missile Command, General Medaris is technical adviser to the Armour Research Foundation and chairman of the Electronics Teaching Laboratory.

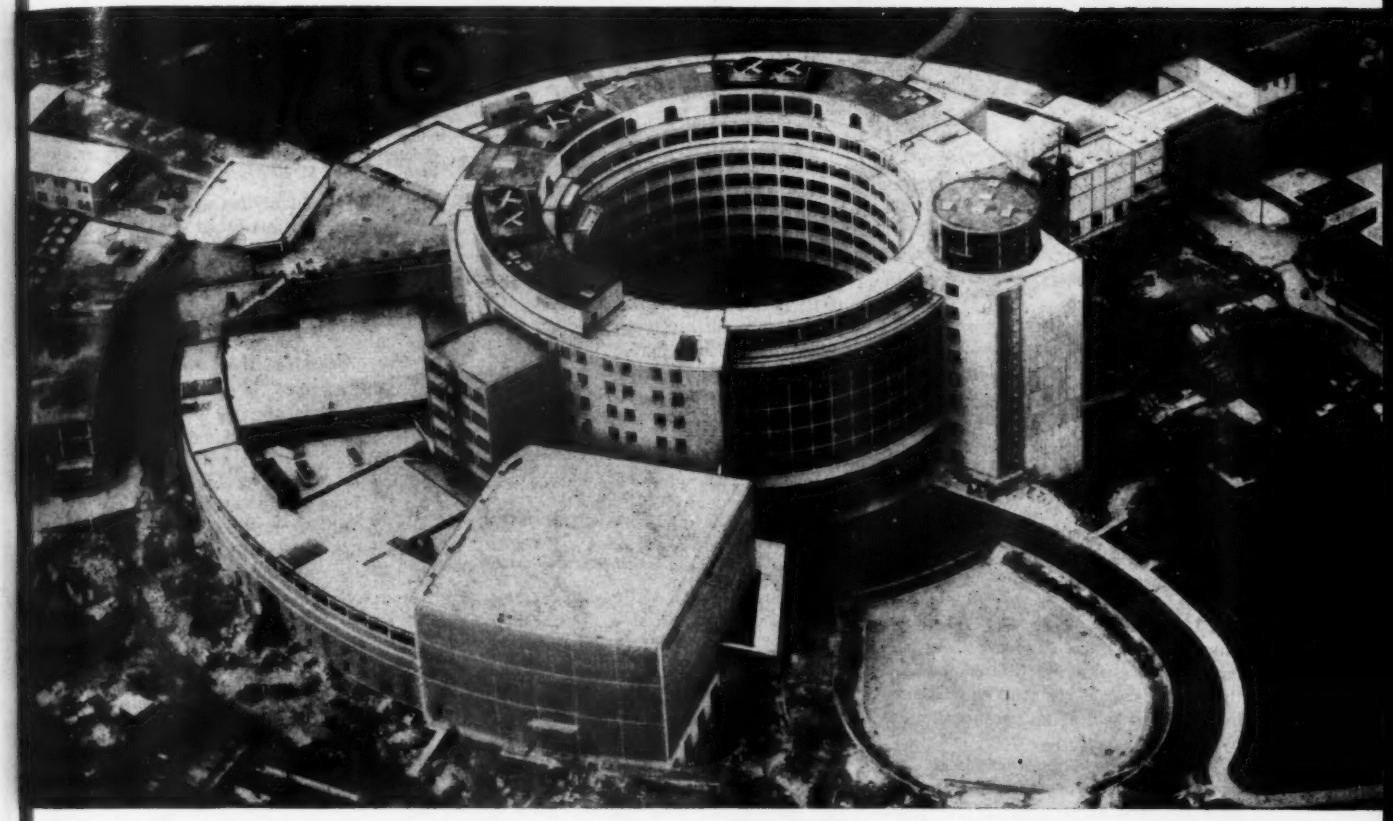
J. B. MEDARIS
major appointment

G. C. ROBERTS
commercial director

One of the more interesting appointments that has caught my eye is that of **Mr G. C. Roberts** as commercial director of Fairey Engineering Ltd. This is a new post and Mr Roberts will coordinate sales policy. He will be based at Fairey's headquarters at Heston, Middlesex. Until recently, Mr Roberts was managing director of Britvic Ltd and a director of Vine Products Ltd. He retains his chairmanship of E. & H. P. Smith Ltd, general engineers, of Birmingham.

UNISTRUT

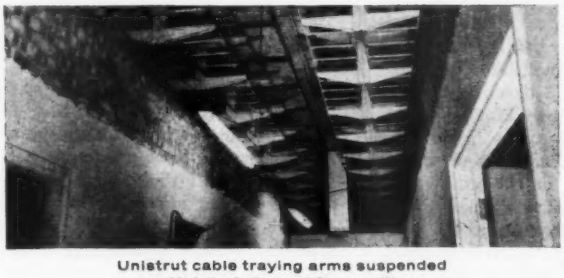
AT THE BBC WOOD LANE TELEVISION CENTRE



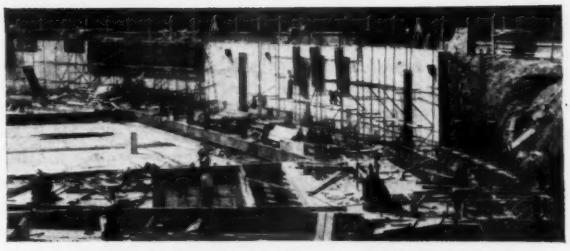
In a building which through its circular form presented a number of installation problems, a new type of Unistrut cable traying arm and the familiar concrete insert (over 3 miles of which have been used throughout the buildings) provide further examples of the versatility of Unistrut.
The traying arms support many miles of coaxial cable carrying sound and vision signals from the nine studios within the centre and from outside sources including Eurovision. The cables descend at frequent but irregular intervals, often in batteries of 400 at a time, to the various equipment bays.

MAXIMUM EASE OF ACCESS

The new Unistrut cable traying arms allow closer spacing with greater ease of access than standard arms previously available, and are suspended from the building structure using standard Unistrut channel and self-locating nut assembly for speed and rigidity.



Unistrut cable traying arms suspended on Unistrut channel from ceiling.



The 250 yd. ring duct under construction. Unistrut concrete inserts were built in at this stage.

RING DUCT WITH CONCRETE INSERTS

Main services are carried below the building in a ring duct approximately 250 yards long with Unistrut concrete inserts embedded, at 2 ft. centres, during the pouring of the concrete. This eliminated the need to pierce for the thousands of fixings required; the cables resting on Unistrut components bolted directly into the inserts—again using the rapid, easily-aligned self-locating nut assembly. The inserts are able to carry a total U.D.L. of about 800 tons, thus limiting the cost of any future expansion required.

UNISTRUT FOR ALL SUPPORT PROBLEMS

For information on the Unistrut system in relation to all support and framing problems—from pipe and cable running to the erection of partitions and even complete buildings, please write to the address below.

GKN

UNISTRUT DIVISION OF SANKEY-SHELDON LTD.

43/45, Broadwater Road, Welwyn Garden City, Herts.
Telephone: Welwyn Garden City 6321 (4 lines)

Book Reviews

Marine applications

Nuclear Ship Propulsion by H. F. Crouch 1960 Cornell Maritime Press, Cambridge (Maryland) 386 pp 87s 6d

An imaginative book, in many ways excellent, yet in others deficient to the point of annoyance. This is perhaps inevitable, since it is written primarily for the nuclear layman—and, to quote the dust cover, in the language of the 'nuclear ship'.

After comparing a nuclear with a conventional installation, the author sets out to delineate the advantages of nuclear propulsion. While admitting that 'it is questionable if the true costs, honestly presented, will ever dip below oil', he suggests that the low fuel consumption, great range and higher cargo-to-fuel ratios of nuclear ships present competitive advantages for fast passenger 'super-liners', ore carriers and oil tankers. An aspect which is neglected is that higher capital costs are compensated in high load factor nuclear installations by lower fuel costs.

Three chapters then summarize the basic features of current reactor designs with the PWR as starting points. There is a tendency to confuse fact and fancy in attempting to describe possible future trends. Clearly the space allocated allows only a very superficial survey, and some distortion is inevitable. While this over-simplified treatment is useless for experts in this field, a fair picture is given of the principles involved, useful for the layman in spite of inaccuracies (such as the curves in Fig. 4-2, convex upwards instead of downwards).

In describing the Savannah installation, the author is on firmer ground; the subsequent chapters on future developments make amusing light reading, even if laced with journalistic mis-statements. Gas-cooled reactors coupled with gas turbines are proposed as the next development, with a UF_6 feed to 'ceramic type' fuel elements and BF_3 control as a possible 'area for technical breakthrough'.

Within the limitations of such a book the chapters on shielding, refuelling procedures, safety and health physics are well presented with minor reservations. Examples of errors are the confusion between *eta* and *p* temperature coefficient effects, misprints in Figs. 11-2 and 11-3, ignoring mass transfer difficulties in 'heavy' liquid shields, confusion in health physics giving rise to such statements as 'generally *m.rem* implies larger permissible doses than μc'.

The book closes with a proposal for an organization to finance further development, and outlines futuristic steps towards fusion reactors for marine propulsion.

It is written exclusively from the American point of view. Although dated 1960, there is no mention of the Lenin, or indeed, of any development outside the United States.

M. C. Hartnell-Beavis

Essential reference

Kempe's Engineers Year Book, 1960, 65th edition, edited by C. E. Prockter, 2 vols, 1324 pp and 1414 pp London 1960, Morgan Bros Ltd, Price £4 7s 6d

Encyclopedic Dictionary of Electronics and Nuclear Engineering by Robert I. Sarbacher, 1960, Pitman, London 1417 pp Price £8

The latest edition of Kempe's handbook, revised yearly, has 120 pages of new tables and text. Some completely new sections of interest deal with 'Electronic Engineering' (this chapter is roughly double the previous one), 'Prestressed Concrete' and 'Naval Architecture'. In all, there are eight completely new chapters and extensive revisions and additions to 12 others; the former chapter on 'Atomic Power', criticized last year as being inadequate, has been revised and renamed 'Nuclear Power'. All information has been checked to bring it into line with the issue of new and revised British Standards.

The author of the *Encyclopedic Dictionary of Electronics and Nuclear Engineering* has spent twelve years over its preparation. Some idea of the effort put into it can be gained from the following figures: it contains over 1,000,000 words, 14,000 entries, 1400 line drawings and 17,000 cross-references. The book is printed in the USA and the definitions and abbreviations used are those approved by official US technical societies and the US Armed Forces. Despite this, a check of selected entries in both the electronics and nuclear fields detected a bias only in favour of US orthography. The table of reactors deals mainly with those of the USA, though the UK civilian reactors each have individual entries. The length and scope of entries is adequate and definitions in fields related to electronics and nuclear engineering are given.

The book is admirably laid out and printed—the line drawings being especially good. And, in fact, it would appear to live up to the claims made of it by the publishers.

D.I.

American GCR symposium

Gas-cooled reactors, Proceedings of the symposium sponsored jointly by The Franklin Institute and the American Nuclear Society, Delaware Valley Section. Monograph no. 7 of The Franklin Institute, 1960 349 pp $5·00

The papers read at this symposium reflect the renewed interest in the USA for the gas-cooled reactor concept. An increasing proportion of US research and development expenditure is being devoted to gas-cooled work largely as a result of the successful programmes in the UK and France and of the advances made, especially in the field erection of pressure vessels of increasing thickness. The development of UO_2 as a fuel material with its characteristics of high temperature operation for long exposures, has also influenced US interest.

The papers are in three groups dealing with: (i) the status of major programmes, (ii) fuel elements and materials, and (iii) components and loop studies. There is also a short report on the Dragon Project, an address by Sir William Cook on the UK programme and a report on the Australian high temperature gas-cooled reactor research programme.

The first section deals with the HTGR, the Army gas-cooled reactor systems, marine gas-cooled reactors, the EGCR, the pebble bed reactor and the Los Alamos 'Turret' experiment. The development of fuel elements and materials for these reactor systems are outlined in a series of papers in the second section. In the third section, three papers outline loop studies and four papers deal with compressors, drives, gas turbines and bearings and the power conversion equipment for the ML-1 plant.

D.I.

Materials for chemists

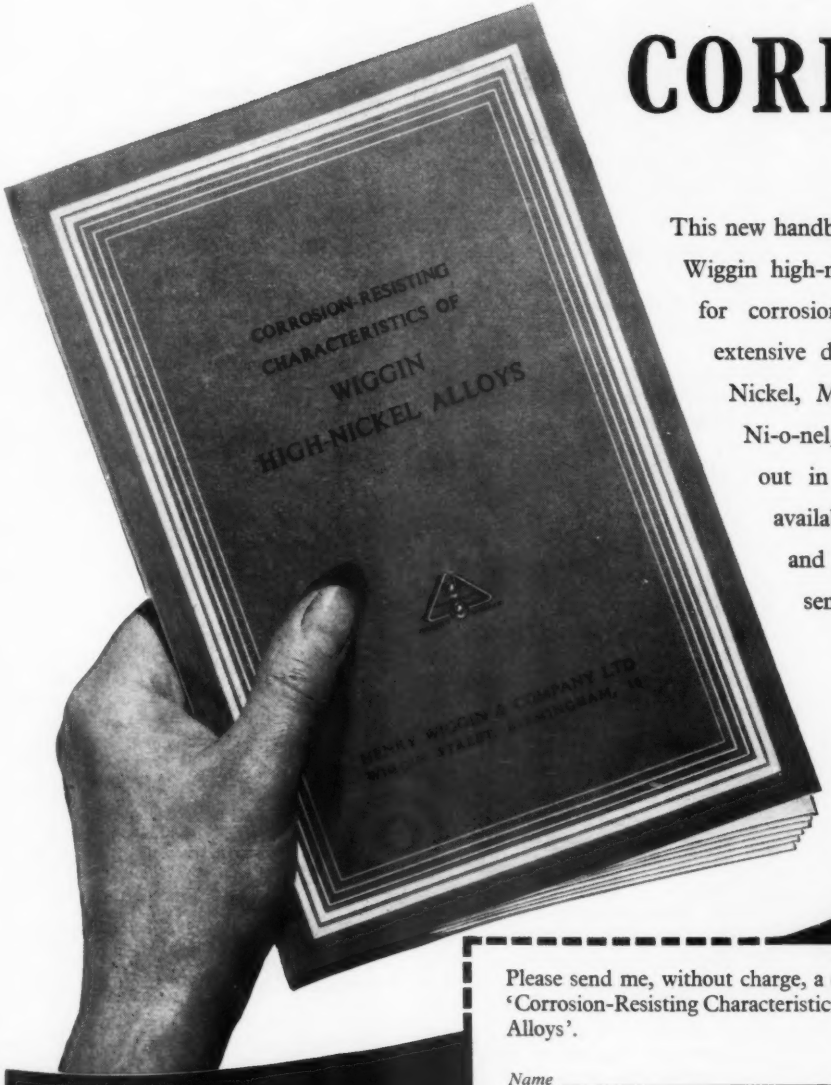
Chemical Engineering Materials by F. Rumford 2nd edition 1960 Constable, London 384 pp Price 32s 6d

The chemical engineering student or draughtsman does not require a large fundamental text to assist him in the study or choice of materials for the construction of chemical plant. His needs are met better with a small and portable volume, which he can keep handy to his desk or board, and in which he will find the general principles governing the choice and behaviour of materials simply explained without a confusing array of detail and the necessary reservations in which a really scientific treatise must necessarily abound.

For six years Dr Rumford's book has met this need capably. The second edition follows the scheme laid down by

Knowing where to find the answers on

CORROSION



This new handbook describes in detail the many Wiggin high-nickel alloys specially developed for corrosion-resisting duties. It includes extensive data on the properties of 'AT' Nickel, Monel, Inconel, Corronel B and Ni-o-nel, and gives results of tests carried out in many corrosive media. It is available, without charge, to designers and chemical engineers. May we send you a copy?

Please send me, without charge, a copy of your publication 'Corrosion-Resisting Characteristics of Wiggin High-Nickel Alloys'.

Name _____

Appointment or Department _____

Company _____

Publications will be sent to private address, if preferred.

NP/C5/10

WIGGIN
***KNOW* NICKEL ALLOYS**

'MONEL', 'INCONEL', 'CORRONEL' AND 'NI-O-NEL' ARE REGISTERED TRADE MARKS

HENRY WIGGIN AND COMPANY LIMITED, WIGGIN STREET, BIRMINGHAM 16

TGA C8

the first in covering the subjects in order of their importance. Chemical plant must be primarily designed for corrosion resistance, and only in a secondary degree for strength and economy, as distinct from normal engineering practice.

The earlier chapters deal with the general mechanism of chemical attack and the essential methods of material testing. Following this, the range of materials available is surveyed, and their relative importance indicated. Fabrication, corrosion resistance and costs are all considered.

Those who own or have consulted the first edition will find very few changes. A careful search has discovered only certain references to the use of materials such as zirconium in atomic energy. The writer, who is aware of many advances in metallurgy can hardly conceive that chemical engineering practice has been able to put them to so little use.

As in the previous edition the last chapter is devoted to plastics, with a new title, 'High Polymers' instead of 'Rubber & Plastics'. The very considerable advances made both in number and variety of these materials has compelled a complete recasting, and the chapter is a valuable introduction to the use of plastics in chemical engineering.

L. M. Wyatt

Nuclear physics

Low Energy Nuclear Interaction and Nuclear Structure. Proceedings of the International Conference on Nuclear Physics, Paris, July 1958, presented by Mme P. Gugenberger 1959 Crosby Lockwood, London 950 pp Price 140s

This handsome volume, as its title implies, is primarily of interest to physicists concerned with recent theoretical and experimental developments in various fields of pure research in low-energy nuclear physics. It does constitute a rather more generally useful handbook than the proceedings of large international conferences usually are, because of the method of presentation adopted for the conference.

More than 150 papers had been submitted on a wide variety of topics (the texts of most of these are reproduced in the second part of the book), but, rather than have them all individually read, the organizers arranged for fifteen speakers, experts in their own particular fields, each to report the essential contents of the relevant papers in the course of a general review of the present status of his topics. Some interesting discussions followed these reports, and all are reproduced in this book. It thus provides some useful and, on the whole, quite readable reviews, still up-to-date, for those interested in obtaining a general impression of the current situation, particularly with regard to theoretical interpretations, and of the trends of interest in low and medium energy nuclear physics. The main topics for the reports were: elastic scattering of neutrons, charged particles and electrons, direct interactions, heavy ions, photonuclear reactions, independent particle and collective models of the nucleus, structure of nuclear matter, and weak interactions. Most aspects of neutron physics were deliberately omitted because of their coverage in another conference.

About eighty per cent of the reports and papers are given in English, the remainder being in French.

J. M. Freeman

New beryllium handbook

Beryllium, by G. E. Darwin and J. H. Buddery Butterworths Scientific Publications, London 1960 392 pp, 113 illus. Price 70s

The first authoritative book to deal exclusively with beryllium metallurgy — 'The Metal Beryllium'—was published by the American Society for Metals in 1955. This contained much information, hitherto classified, collected within the Manhattan Project from the laboratories of the Massachusetts Institute of Technology. It was realised, however, by the editor of the Butterworth Series of Monographs on the Metallurgy of the Rarer Metals—Dr H. M. Finniston, the then Head of the Metallurgy Division at A.E.R.E. Harwell—that this publication left much to be desired as a reference book. He therefore commissioned two members of the division to complete a volume that could join the other six books in the series, one that would combine the information from both American and British laboratories. After five years, this task has now been completed and published.

It is, without doubt, an impressive document, in which the data from over 600 sources has been collected, sieved, and abstracted. Apart from the conventional information on production, fabrication, physical and mechanical properties, there are chapters on the world's ore resources, the preparation and properties of beryllium-ware, the chemical and nuclear properties of beryllium, and a section on health hazards and their control. A very comprehensive chapter on the alloying characteristics of beryllium is also included.

Unfortunately, as with most reviews, the information is presented in a somewhat encyclopædic style with little attempt to differentiate between the dubious data and the more authentic. In some cases, also, the conclusions derived by the original authors have been repeated although, in the light of more recent data, they require modification. These errors are few, however, and are unlikely to confuse readers who are working in the beryllium field. Undoubtedly this book is primarily aimed at this select body of men, but its clear style and excellent presentation will appeal to all who wish to become acquainted with the subject.

A. J. Martin

Top people

Who's Who in Atoms 1960, Advisory Editor A. W. Haslett, 2nd edition, Vallancey Press, London 983 pp, 2 vols Price £10 10s

This is one of the more valuable reference works and, with its new clear type, is a marked improvement upon the first edition which, incidentally, was out of print within two months of publication. The two volumes contain over 12,500 names, providing biographical information on persons in the nuclear field in over 70 countries. While there are inevitably, in a work of this kind, some omissions that will be pointed out, this does not detract from its worth; any such additional details thought necessary will no doubt be inserted in the third edition which is being prepared for publication early next year.

S.H.

New Books

● *Neutron Detection* by W. D. Allen, Newnes, London 1960 260 pp Price 45s
★ 262

● *X-Ray Powder Photography in Inorganic Chemistry* by R. W. M. D'Eye and E. Wait, Butterworth 1960 222 pp Price 45s.
★ 263

● *Computer Engineering* edited by S. A. Lebedev (translated from the Russian) Pergamon Press, London 1960 184 pp Price 63s
★ 264

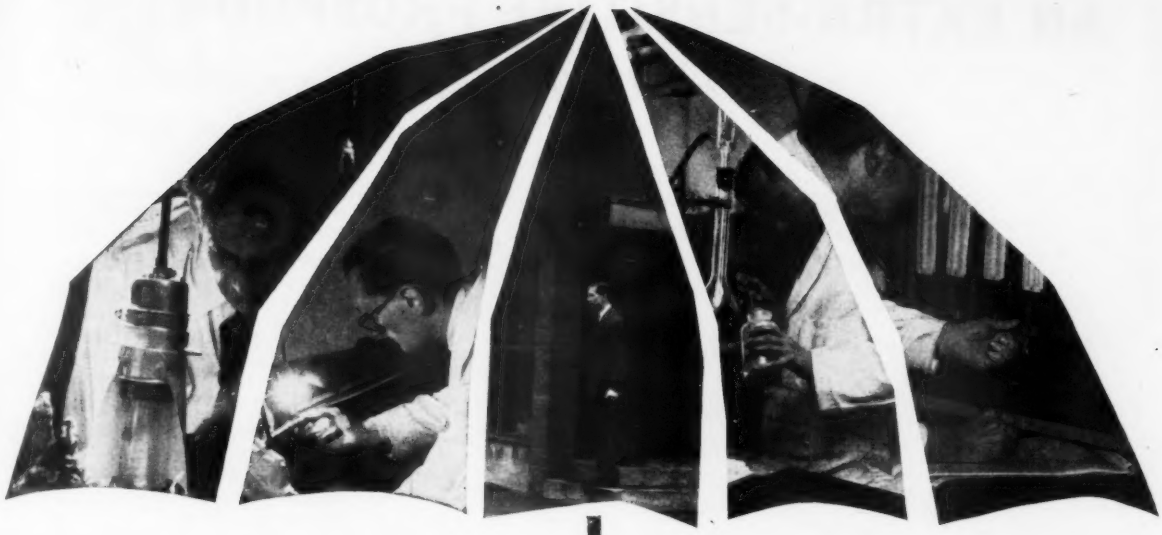
● *Progress in Nuclear Energy Series IV*— Technology, Engineering and Safety, volume 2, edited by R. Hurst and others Pergamon Press, London 1960 799 pp Price £5 5s
★ 265

● *High Energy Nuclear Physics* by W. O. Lock Methuen, London 1960 190 pp Price 18s
★ 266

● *Procedures for Obtaining Properties of Steel at Elevated Temperatures* B.S.3228. 1960 Part I: Proof stress British Standards Institution, London Price 3s
★ 267

● *Temperature Induced Stresses in Solids of Elementary Shape* by L. H. Adams US National Bureau of Standards, Washington 1960 27 pp Price 25 cents
★ 268

★ For further information on any item circle the appropriate number on the reply card facing page 147.



NUCLEAR SAFEGUARDS

Hand and Clothing Monitor

Portable Monitor

E.M.I. INSTRUMENTS PROTECT AGAINST RADIATION HAZARDS

The Hand and Clothing Monitor has been specially designed to cope with large numbers of staff. Whilst Alpha and Beta contamination are being simultaneously checked on both hands, the footwear and clothing of two other workers are being screened.

The speed, simplicity and safety of E.M.I.'s new Monitor have been recognised by large orders from the U.K.A.E.A. and authorities in many other countries.

- ✳ Complete Alpha and Beta hand count in 5 seconds.
- ✳ Audible and visible warning of the maximum permissible contamination level.
- ✳ Audible warning if hands are removed too soon.
- ✳ Dual phosphor scintillation counters for increased efficiency in tropical and humid environments.
- ✳ Automatic correction for background radiation.

The Portable Monitor is the answer where mobility is required. Compactness *and* high accuracy have been achieved by combining all-transistor circuitry with the E.M.I. dual phosphor technique. This instrument, developed in close collaboration with U.K.A.E.A., marks a really significant step-forward in radiation detection.

- ✳ Simultaneous monitoring of Alpha-Beta radiation, giving aural and visual warnings.
- ✳ Transistors throughout for reliability, lower power consumption and long life.
- ✳ Battery operation for real portability (mains unit available if required).
- ✳ High accuracy over wide temperature range.

Write or telephone now for a demonstration and full details

E.M.I. ELECTRONICS LTD

INSTRUMENT DIVISION · HAYES · MIDDLESEX

TELEPHONE: SOUTHALL 2468

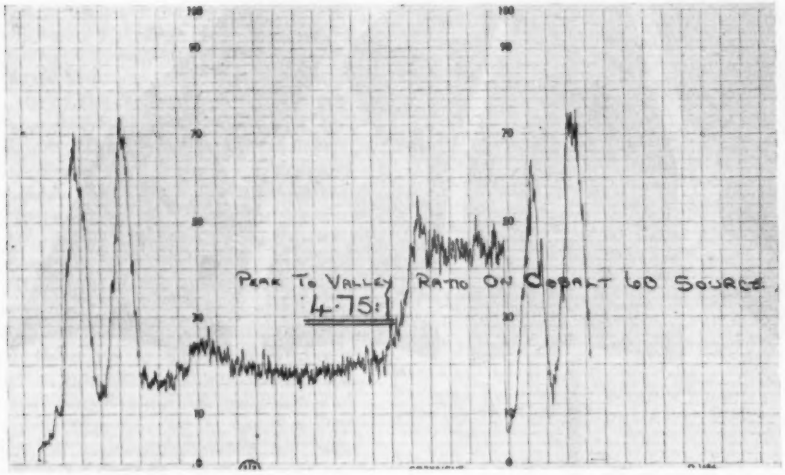
EE 113

Circle **No 69** on reply card for further details

Circle **No 70** on reply card for further details

AN EXTRA-SENSITIVE PHOSPHOR

Crystal-with-Photomultiplier



The thallium-activated sodium iodide crystal is mounted direct on a photomultiplier.

HIGH RESOLUTION
Peak-to-valley ratio of 4:1 with a Cobalt-60 source.

LOW BACKGROUND
Background radiation is due entirely to Potassium-40, and does not exceed 8 counts per second.

PHOTOMULTIPLIER PROTECTION
The photomultiplier is never exposed to direct light, and so its efficiency is preserved.

3-inch assemblies and 1-inch counting probes. Catalogue CJ 39/c55 for details.

HILGER & WATTS

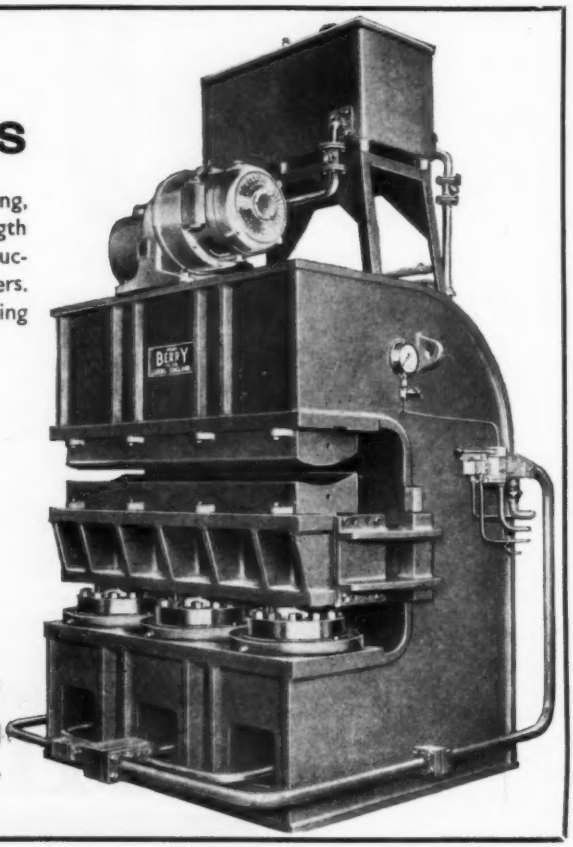
HILGER & WATTS LIMITED 98 ST PANCRAS WAY · LONDON NW1 · *Tel GULliver 5636*

HYDRAULIC
PLATE CURVING PRESS

The press is made with dies varying from 3′ to 8′ long, but it will progressively curve plate edges of any length prior to rolling. The frame is of all welded steel construction and has two or more upstroking rams and cylinders. These presses can be made to work from an existing hydraulic supply or supplied with electrically driven self-contained pumps.

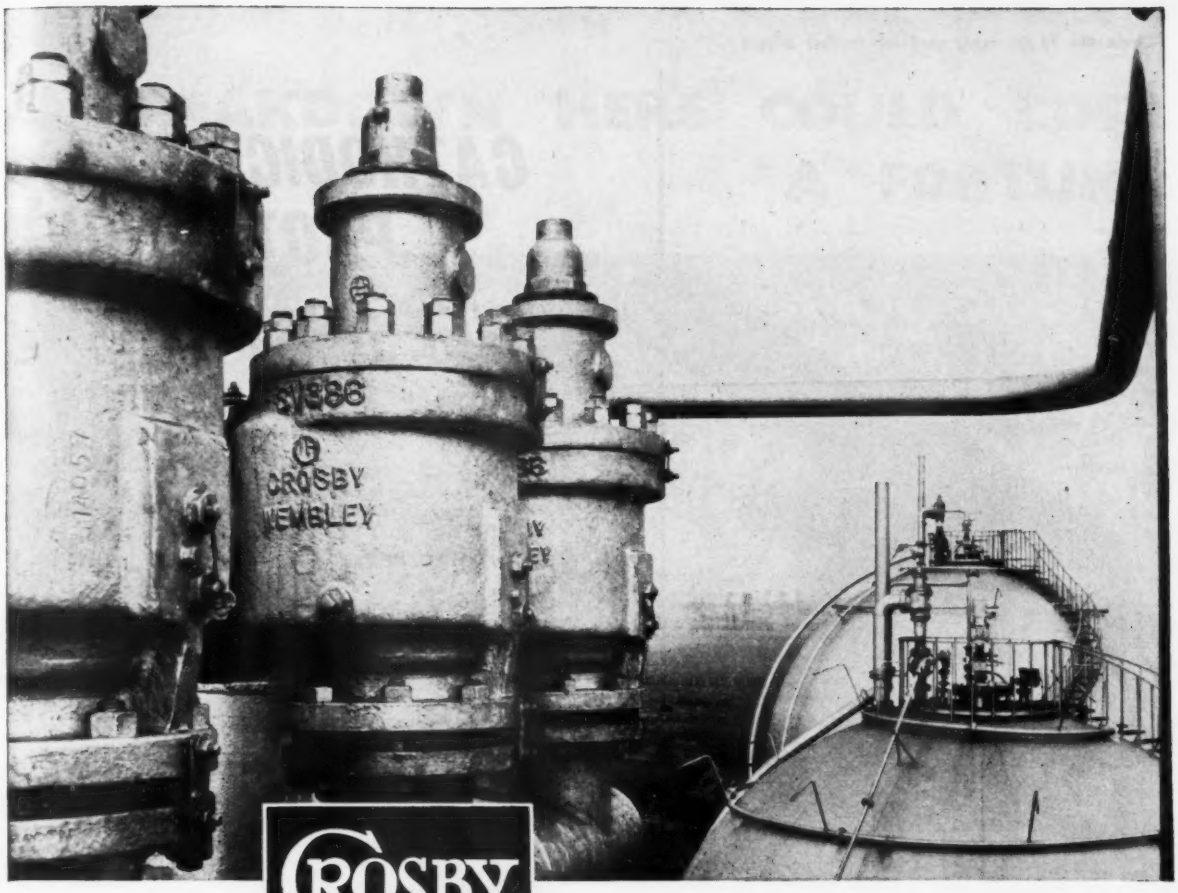
We also manufacture:

High Pressure Hydraulic Plant for Shipyards, and Railway Workshops, Plate Bending Rolls, Punching and Shearing Machines, Continuous Finishing Presses for Silks and Rayons, Veneer and Plywood Presses, Cotton Baling Presses, Die Spotting Presses, Pumps, Accumulators, Valves and Intensifiers.



HENRY BERRY & CO. LTD.
CROYDON WORKS, LEEDS 10

TEL: LEEDS 75481-2 GRAMS: "RIVETTER LEEDS 10"



CROSBY

MASONEILAN

SHELL USE EQUIPMENT AT SHELL HAVEN

Illustration shows three of four 6 x 8 Crosby Relief Valves together with Masoneilan Liquid Level Transmitters mounted on each of three Butane Storage Horton Spheres at Shell Haven. These relief valves protect the tanks from overpressuring.

The level instruments transmit the level of liquid Butane in the Spheres back to the Receiver in the control room. The reliability of this equipment is thus exemplified once again by one of the major oil companies of the world.

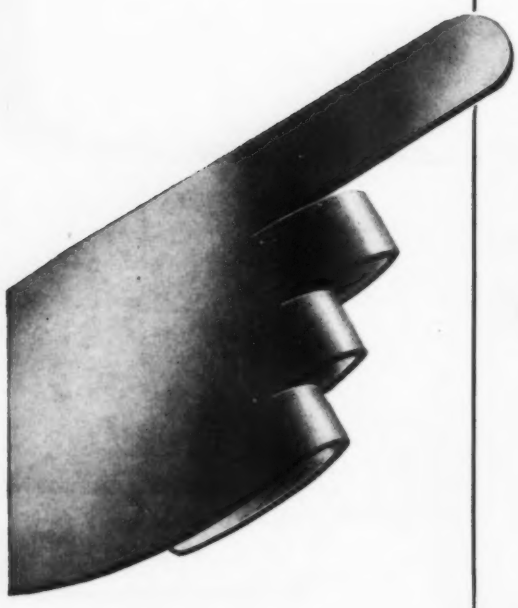
IMPORTANT ANNOUNCEMENT

Details are now available of the Crosby portable self-contained Safety Relief Valve Test Stand for Works or Site test purposes.

CROSBY VALVE & ENGINEERING CO. LTD., CROSBY WORKS, WEMBLEY, MIDDLESEX
Telephone: Alperton 2311

CHWR/1960/Ia

Circle **No 73** on reply card for further details



CATHODIC PROTECTION?
WELDING INSPECTION?

Get the facts from

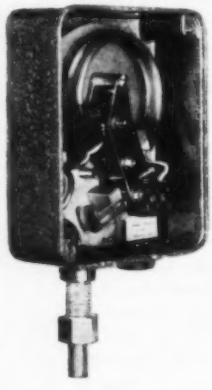
MAPEL

World-Wide Service

METAL AND PIPELINE ENDURANCE LTD.,
30 London Road, Woolmer Green, Herts.
Tel: Knebworth 3083. Grams: Metaldure, Knebworth.

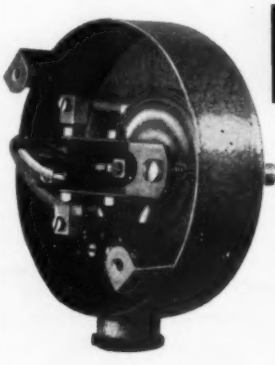
Other offices at London, Newcastle-upon-Tyne and Glasgow.

TWO PRESSURE SWITCHES by K.D.G.



BOURDON
150 p.s.i. to 5000 p.s.i.

For use with liquids or gases, and may also be supplied with Stainless Steel elements for corrosives. Contact rating 5 amps at 250 volts A.C. Also available in weatherproof and flameproof housings.



DIAPHRAGM
up to 100 p.s.i.

Of simple and robust construction, this switch will withstand overload pressures up to 20% above the maximum working range. For use with non-corrosive gases or liquids, minimum range 0·5″ to 30″ w.g. Maximum 100 p.s.i. Also available in moisture-proof, water-proof and flameproof housings. Ideal for 3-15 p.s.i. pneumatic applications, supplied with and without setting dial.

Full details and specifications of the complete K.D.G. range are readily available from:

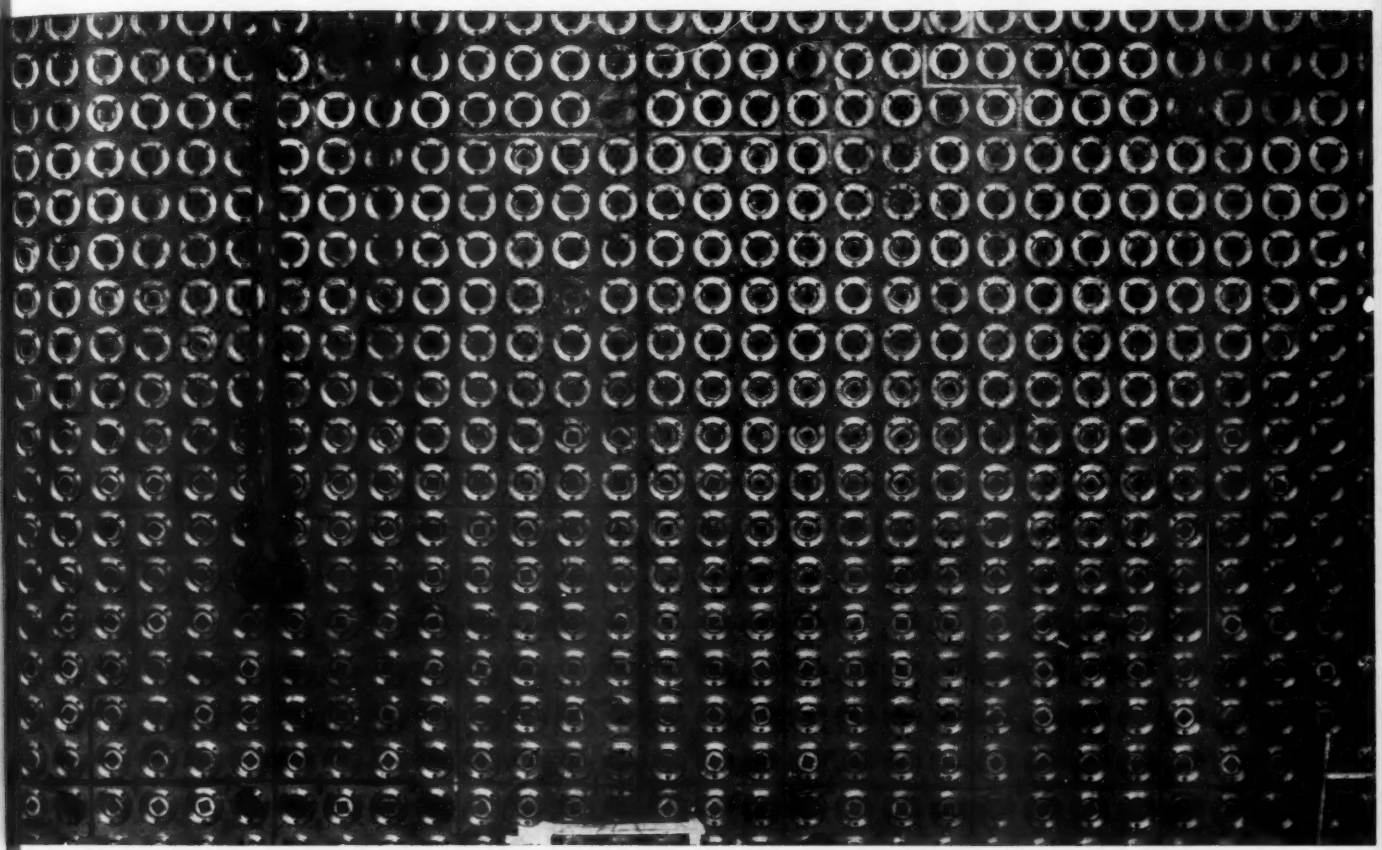
K.D.G. INSTRUMENTS LTD IN ASSOCIATION WITH STOW & PARTNERS LTD

MANOR ROYAL · CRAWLEY · SUSSEX TEL: CRAWLEY 25151

LONDON SHOWROOMS, SERVICE AND SALES: 100 FLEET STREET, LONDON, E.C.4. Telephone: FLEet 5354/5

CRAWLEY KDG LONDON

A BREAKDOWN HERE COULD COST A FORTUNE



What is the most important piece of machinery in your factory ?

What would be the cost per day to your business if it were to break down ?

It is now possible to cover the loss of profits resulting from such a breakdown as well as the cost of repairing the machine itself.

Policies can be issued to meet the particular requirements of any business.

In this way you can be indemnified against the serious interruptions to your business which can be caused by machinery breakdown.

Should you feel in need of the protection of this new form of insurance we can send an engineer to advise you and inspect your plant.

Write to **D. H. EVERS,** *Industrial insurance consultant*

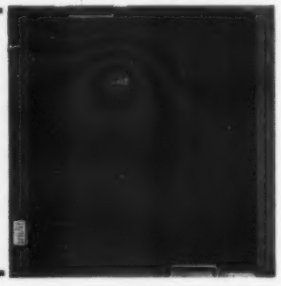
ONE ARUNDEL COURT JUBILEE PLACE LONDON S.W.3

Circle **No 76** on reply card for further details

HAIR OR AIR?

Both! One used in conjunction with the other! That's been our business for a long time and we've built up a vast stock of experience and know-how in the process!
Every Heather Air Filter uses a finely graded screen of intermingling hair to trap dust particles and impurities from the incoming air-stream. And, what's most important, this unique, low-cost filter system does not need special cleaning equipment, fluids, replacement pads or fabrics. So why waste money on expendable filter elements and replacements when a Heather Filter can be cleaned for further use simply by shaking, washing or suction cleaning?
If *you* want full details write for our new catalogue No. 42.

Here is a Heather Multi-Brush Air Filter But do you also know about our range of money-saving Satomair Humidifiers? Send for our new catalogue and we'll forward details of these as well.



HEATHER FILTERS LIMITED

7 KENDALL PLACE · BAKER STREET
LONDON · W.1. HUNTER 1801

Circle **No 77** on reply card for further details

Vital Protection

in Pile Cap Area

Fuel Preparation Rooms

Hot Examination Areas

and all laboratories using

Radioactive Materials

ATOMICOTE

DECONTAMINABLE COATING

TESTED and APPROVED by A.F.R.E. HARWELL

PROTECTIVE DETEL COATINGS DEFIES CORROSION

DETEL

PRODUCTS LTD

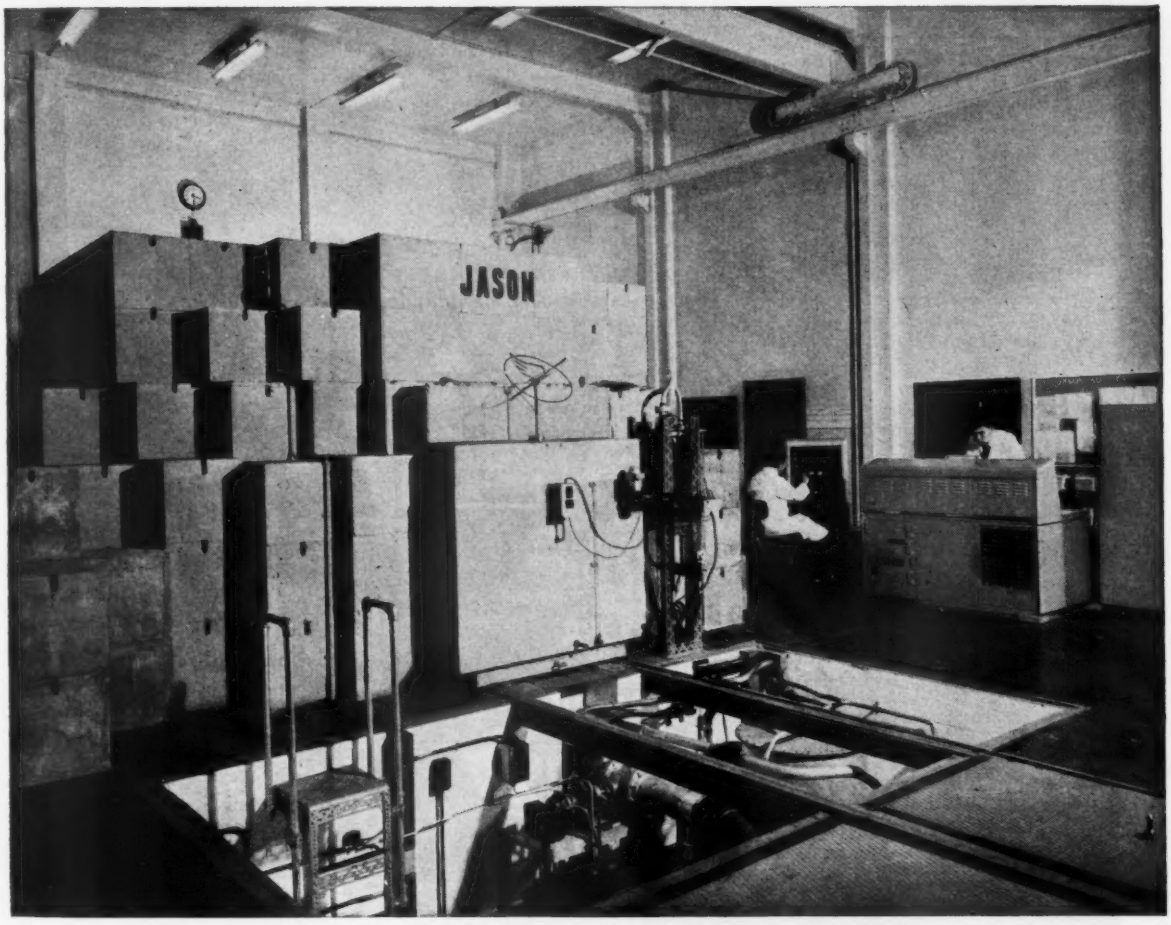
SOUTH RUISLIP, MIDDLESEX

RUISLIP 6041/2

COMPACT, VERSATILE AND MODERATE IN COST

Jason

THE PRACTICAL REACTOR FOR RESEARCH AND TRAINING



Hawker Siddeley's Jason reactor provides a large source of neutrons at low power, is ideal for student training and activation experiments and for the production of short-lived isotopes for medical research. Jason, which is basically similar to the Argonaut, has five forms, offering a wide range of facilities and powers from 1 to 100,000 watts. Around the central annular core in the cubic graphite reflector can be placed a shield tank, beam holes, thermal columns or lattice experiments up to four in number. A further lattice experiment can be placed above the core. Up to 10 beam holes and 3 rabbit facilities can be incorporated. Using 20% or 90% enriched uranium, the flux ranges up to 2 x 10^{12}n/cms.^{2}sec. Irradiation facilities are available in the standard Jason which is now operating at Langley. Terms on application.

JASON reactors are now under construction for United Kingdom Energy Authority, Winfrith Heath and Reactor Centrum Nederland, Petten, Holland.

HAWKER SIDDELEY NUCLEAR POWER CO. LTD.

SUTTON LANE, LANGLEY, BUCKS. / MEMBER OF HAWKER SIDDELEY GROUP

Circle **No 78** on reply card for further details

Circle **No 79** on reply card for further details

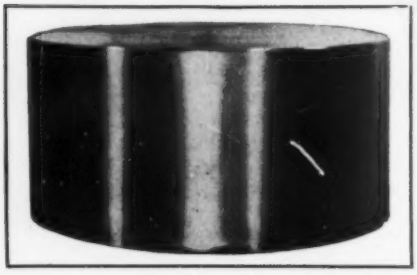
G.E.C.

HEAVY ALLOY

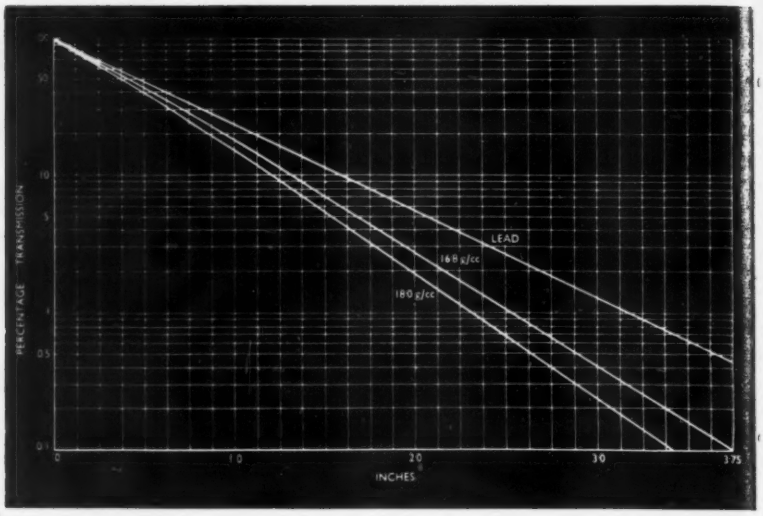
supplied in densities

16.8,17.0,17.5,18.0g/cc(nominal)

- ***for screening purposes***
- ***for balance weights***

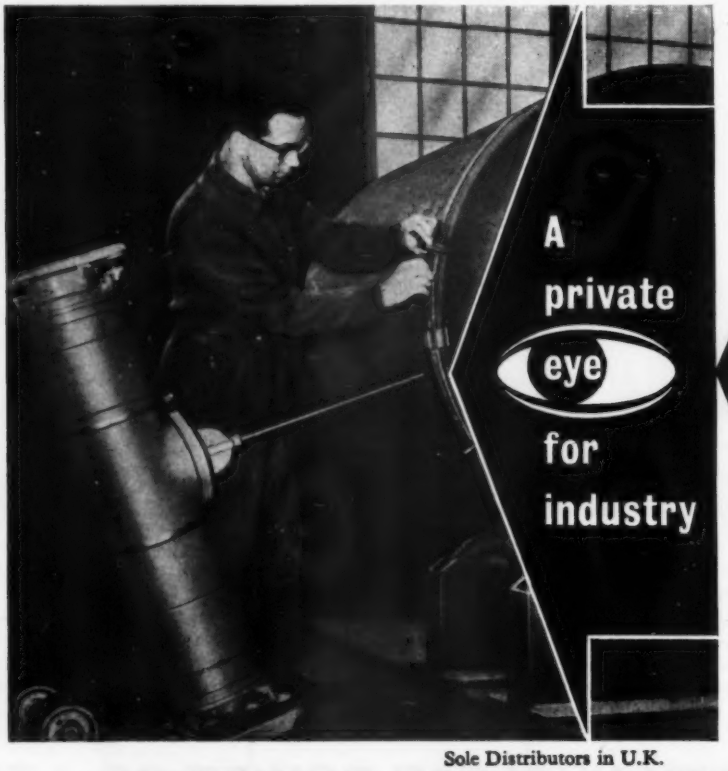


The above piece of G.E.C. Heavy Alloy was made for the United Kingdom Atomic Energy Authority. It weighs 660 lb.



Broad beam absorption of Gamma-radiation from COBALT-60. Density: 16·8 g/cc. and 18·0 g/cc.

THE GENERAL ELECTRIC CO. LTD., Component Sales Dept., Osram Metals, East Lane, Wembley, Middlesex. Arnold 4321



Ruggedly built, but still mobile, the Muller Macrotank H is specially developed for on-site radiographic examination in heavy industry, ship and bridge building, nuclear power and refinery construction — wherever complete and accurate weld examination is essential. The small focus (2.3 mm.) of the Macrotank H gives really sharp definition, with a penetration of up to 2¼" of steel with Pb screens in reasonable exposure time. It is low in cost, reliable in use, and backed by full service facilities which may be on contract if desired. We shall be glad to send you full details.

The Macrotank H is a product of C. H. F. Muller, Hamburg.

Sole Distributors in U.K.

RESEARCH AND CONTROL INSTRUMENTS LIMITED

Instrument House, 207, King's Cross Road, London, W.C.1. TERminus 2877

(RCI.6416A)

canned power

The integrity of a can is vital in many fields, but in none more so than nuclear engineering. The present generation of nuclear power stations will make extensive use of canning materials developed and produced by MEL. They will help to ensure the safety and maintain the economic performance of this vital new source of energy.

MEL have also developed techniques for the separation of zirconium and hafnium and for the production of vanadium and can supply:
Zirconium compounds with a hafnium content down to 100 p.p.m.
Hafnium compounds with a zirconium content of 2%
High Purity Vanadium Metal

Magnesium Elektron Limited

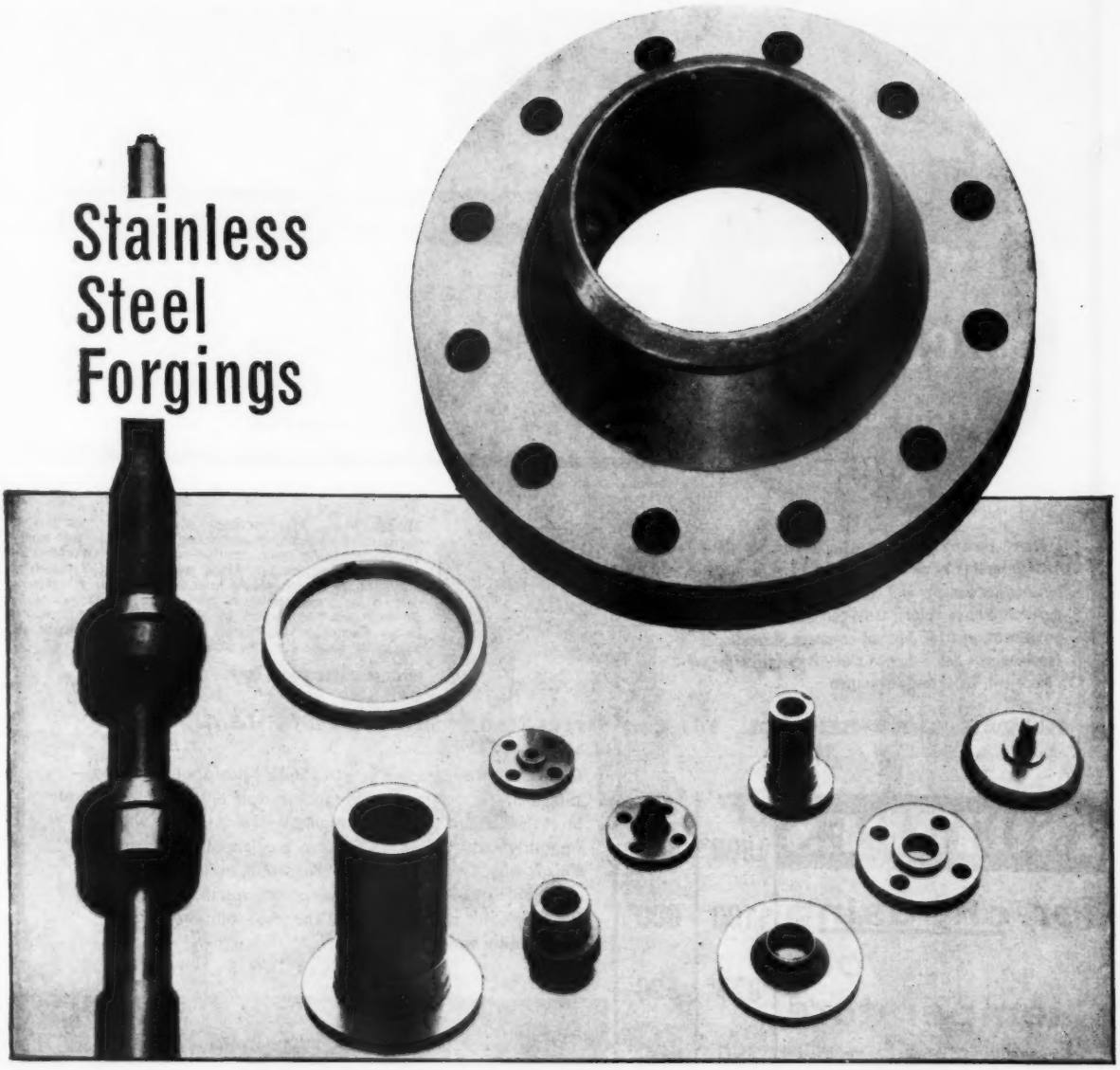
Clifton Junction Manchester *Swinton 2511*
London Office: 5 Charles II Street St. James's SW1 *Trafalgar 1646*
Magnesium Elektron, Inc., New York 20, USA

Circle No 81 on reply card for further details

TO DESIGNERS, PROTOTYPE & MAINTENANCE ENGINEERS
A 24 hr Service
FOR
ELECTRONIC COMPONENTS
We produce a comprehensive range of high-quality Electronic Components. Consult our catalogue for your requirements. Our "By Return" Service will ensure immediate despatch of your orders.
Radiospares Ltd.
4-8 MAPLE STREET · LONDON · W.1 · ENGLAND
Telephone: EUSton 7232-9
Telegrams: RADOSPERES, WESDO, LONDON. Cables: RADOSPERES, LONDON.
RS

MUREX manufacture
ductile
NIOBIUM
ROD, WIRE, SHEET & TUBE
Write for full technical information
MUREX LTD. (Powder Metallurgy Division) RAINHAM · ESSEX
Telephone: Rainham, Essex 3322 Telex 28632 Telegrams: Murex Rainham-Dagenham Telex
LONDON SALES OFFICE: CENTRAL HOUSE, UPPER WOBURN PLACE, W.C.1

Stainless Steel Forgings



serving Atomic Energy, Aircraft and Oil industries

Manufactured to any British or U.S.A. Standard Specification
Supplied as Forgings only or Fully Machined in Modern Machine Shops on approved lists of A.I.D., A.R.B. and LLOYDS.

William Oxley & Co. Ltd.

PARKGATE STEEL WORKS · ROTHERHAM
telephone Rotherham : 5238

Circle **No 85** on reply card for further details

new advancements in NUCLEONICS from U. S. A.

Frazar & Hansen Ltd., internationally known since 1834, presents many leading U.S.A. manufactured nuclear instruments and components, including monitors and detectors, radio-chemical analysis equipment, nuclear medical scanners, educational teaching aids and radiation shielding and protective equipment. **Write for information.**

Single Channel Remote Area Monitor

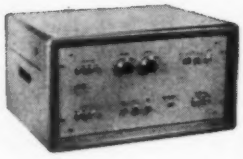
Model GA Series. Available in the GA-3 series with 2-point electronic calibration, in the GA-4 series with the same and with the addition of " source check " feature, and in the GA-5 series with 2-point source (SR-90) calibration only. The GA series offers any continuous combination 3 decade logarithmic ranges from ·01 mr/hr to 100,000 R/hr. Energy dependence is flat to within plus or minus 10% from 80 KV to 1·2 Mev.

RIGGS NUCLEONICS

Alpha Floor Monitor

Model FM-3G. Designed to enhance the surveying of floor surfaces of research, operation, or production areas where alpha-emitting radioactive materials are present. Its high sensitivity, large area probe searches out hidden alpha contamination not readily detectable with ordinary portable alpha survey instrumentation. Eliminates delays involved in " smear or wipe " techniques. Well balanced and self-contained. 2 pi geometry meter readout determines immediately the contamination status of an area.

EBERLINE INSTRUMENT CORP.



Coincidence Radiation Analyzer

Model 704. Measurement of minute quantities of radioactive material is enhanced by coincidence analysis. By counting only simultaneous pulses, background is virtually eliminated. Used with a wide selection of single channel analyzers, linear amplifiers. It employs delay line compensation for transit time of single channel analyzers used in a coincidence experiment. Delay lines easily modified to suit transit time of the particular single channel analyzer in use.

INTERSTATE ELECTRONICS CORP.

FRAZAR & HANSEN Ltd., 301 Clay Street, San Francisco, Calif., U.S.A.

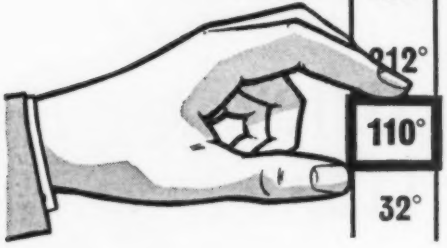
ISOTAPES

for **choosing** your temperature

Illustration shows Isotapes (before application of lagging) as installed by Babcock & Wilcox Ltd., at the Generating Station of the C.E.G.B. at Plymouth.

Write for latest catalogues on surface heating units.

°F	°C
1500°	800°
1100°	600°
925°	500°
750°	400°
570°	300°
400°	200°
212°	100°
110°	50°
32°	0°



Choose any temperature you like in this new foolproof way. Finger-tip control by thermostats, ensuring an even temperature level throughout your entire piping system. Liquids will flow smoothly and freely down pipes of any length or gauge. This is what Isopad offer you. No waste, no clogging and no troublesome blockages, however extreme the conditions. It's simple, it's clean, it's safe. The ideal solution to pipe-heating worries.

ISOPAD ELECTRIC SURFACE HEATERS **ISOPAD LIMITED** Barnet By-Pass, Boreham Wood, Herts.

Phone : ELStree 2817/8/9

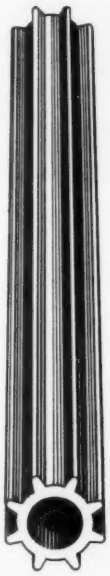
Some recent developments in manufacturing techniques and special applications of tubes in a variety of metals . . .

No. 12 OF A SERIES BY ACCLES & POLLOCK

Four-finned tube made from stainless steel 18/8/1 quality. The corners on each of the fins are radiused.

Hairpin bi-metallic tubes consisting of a mild steel outer tube 1″ o/d x 10g. having 12 equi-sized internal channels .064″ deep. Overall length 7′ 6″. Limits on o/d ± .003″ including ovality. This is drawn tightly on to a stainless steel inner tube ¾″ o/d x 18g. x 7′ 6″ overall length. The mild steel fins are welded on to the tube assembly.

Eight-finned stainless steel tube .312″ circular bore x .050″ body wall thickness and .590″ across fins. Each fin .090″ high, tapering from 1/16″ at base to 1/32″ at apex.



Designers have a habit of asking for the impossible, but in a surprising number of cases Accles & Pollock produce an answer that enables the production people to translate the concept on the drawing-board into a physical, functional form. Accles & Pollock welcome all such opportunities to co-operate in developing new applications in the form of tubes and tubular sections.

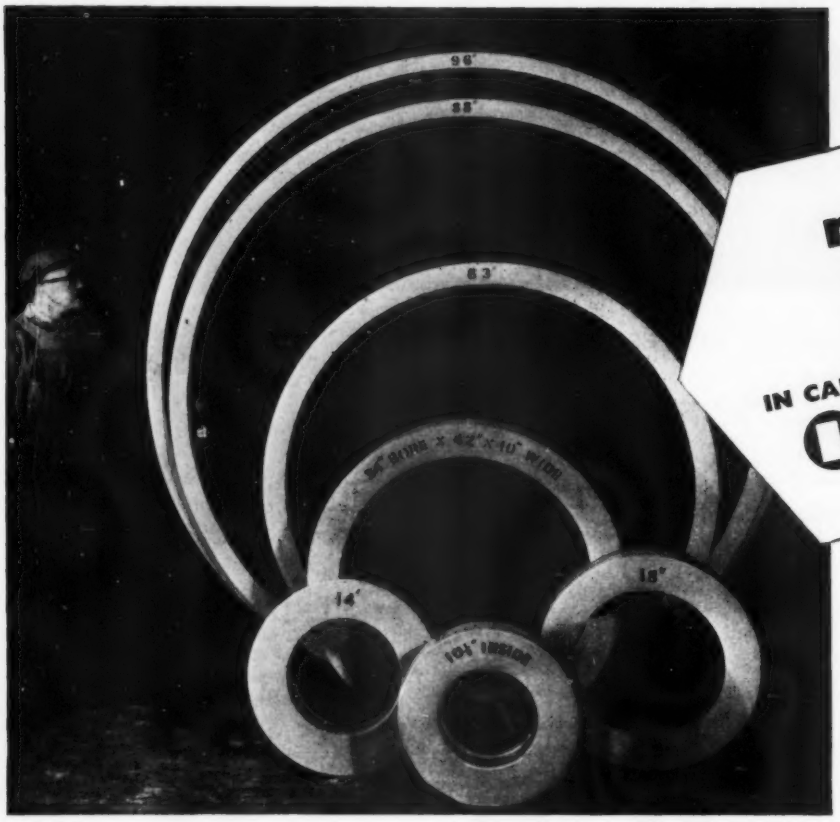
Accles & Pollock

Technical Information Sheets discussing tubes and their applications are available on request.

ACCLES & POLLOCK LIMITED · OLDBURY · BIRMINGHAM · A TI COMPANY

Makers and manipulators of COLD DRAWN SEAMLESS and WELDED PRECISION TUBES in carbon and alloy steels, including stainless steel, and other metals.

TBW 298



rolled steel rings

IN CARBON AND ALLOY STEELS

Plain rectangular and special sections from 96" outside dia. to 10⅛" inside dia.

Leaflet giving full details of manufacturing capacity available on request.

JOHN BAKER & BESSEMER LTD

KILNHURST STEEL WORKS,
G.P.O. BOX No. 3 ROTHERHAM
TELEPHONE: MEXBORO' 2154/7 & 3793
TELEGRAMS: TYRES MEXBORO'

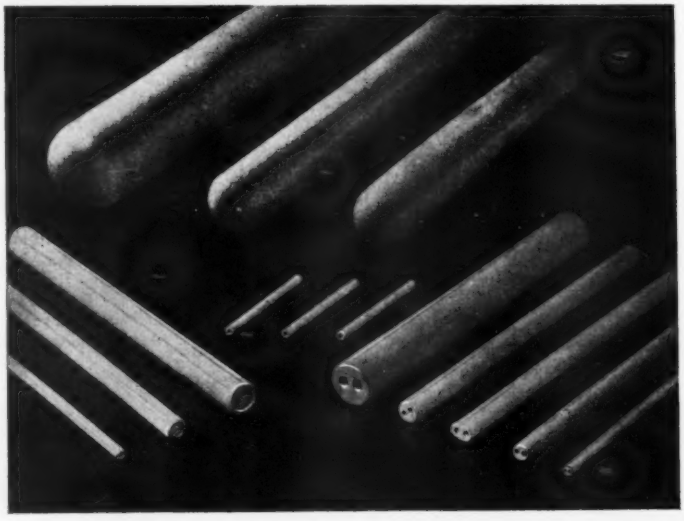
LONDON OFFICE:

LOCOMOTIVE HOUSE BUCKINGHAM GATE SWI
TELEPHONE: VICtoria 5278-9

P.3821

Where PYROMETRY prevails . . .

Higher Process temperatures demand accurate thermal control, and reliable pyrometer sheaths and thermocouple insulators are now an essential. Thermal aluminous porcelain, mullite and pure recrystallised alumina sheaths and insulators are used up to 1,500°C., 1,700°C. and 1,900°C. respectively, for temperature measurements in gas, oil and electrically heated furnaces, flues and pipelines.



- *Thermal Fused Alumina and Fused Magnesia powders and cements are also available.*
- *We also manufacture an extensive range of Vitreosil Laboratory Ware.*

TSL

THE THERMAL SYNDICATE LTD.

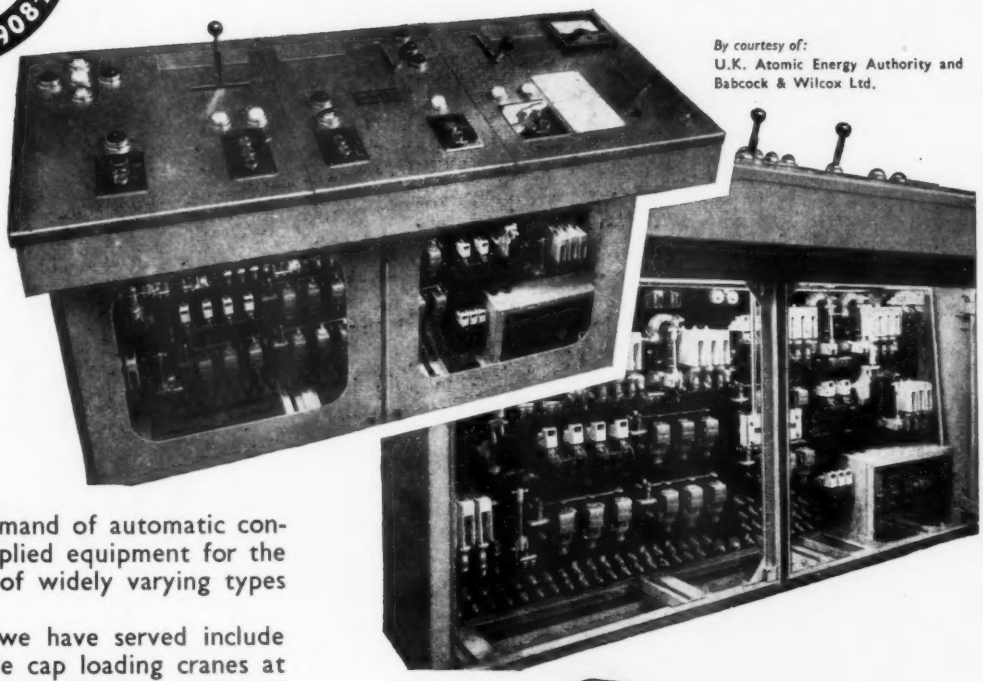
P.O. Box No. 6, WALLSEND, NORTHUMBERLAND. *Telephone: Wallsend 62-3242/3*

LONDON, 9, BERKELEY STREET, W.1. *Telephone: Hyde Park 1711/2*

THE SIGN OF QUALITY
EMB
ESTABLISHED 1908

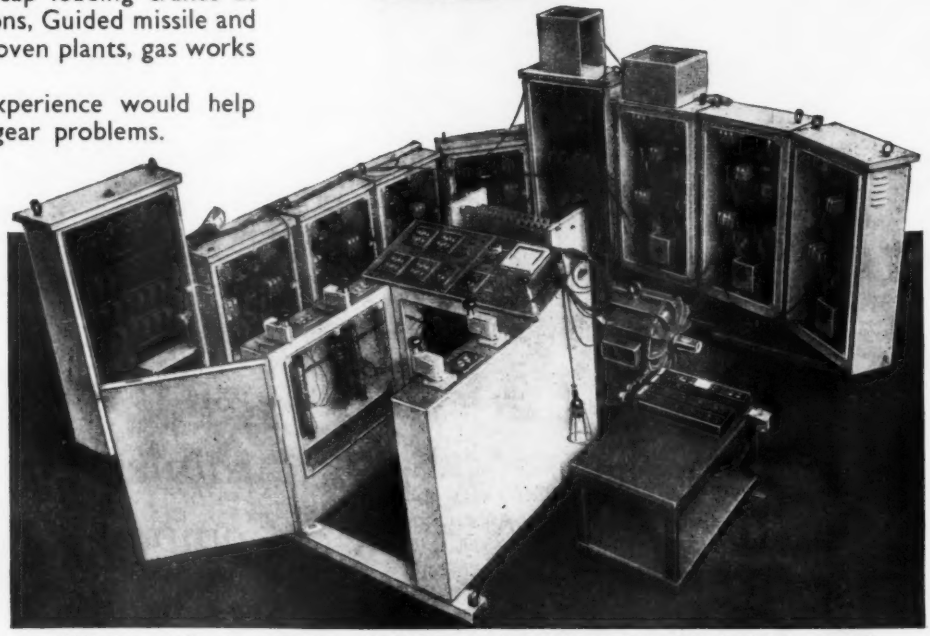
Control Gear

By courtesy of:
U.K. Atomic Energy Authority and Babcock & Wilcox Ltd.



Control desk for the Babcock Mechanical Handling plant at Chapelcross.

To meet the demand of automatic control, we have supplied equipment for the electrical control of widely varying types of installations.
A few of those we have served include equipment for pile cap loading cranes at Atomic Power Stations, Guided missile and Rocket bases, Coke oven plants, gas works skip hoists.
Maybe our wide experience would help solve your control gear problems.



E.M.B. Control Gear incorporating a MICROsen speed control unit being tested prior to despatch to Berkeley Atomic Power Station for pile cap handling equipment.

E.M.B. Co. Ltd.

WEST BROMWICH
Phone 1171
ENGLAND

Circle **No 90** on reply card for further details

Circle **No 91** on reply card for further details

WESTON

MOVING COIL

RELAYS

The simplicity and reliability of relay control for a wide variety of applications has led to the ever increasing use of Weston Moving Coil Relays. Let us have a note of your relay problems and we will be pleased to advise on the most suitable model for any set of conditions. Enquiries should, if possible, be accompanied by full particulars of both control and local circuits.

Illustrated is the Model S170. Other types include the Model S124, a magnetic contact relay which operates with a minimum power input of 0.004 microwatt and the Model S115, a miniature relay, which functions as an "on-off" switching relay.

SANGAMO WESTON LIMITED
ENFIELD · MIDDLESEX
Tel: ENField 3434 (6 lines) & 1242 (6 lines) Grams: Sanwest, Enfield

Scottish Factory: Port Glasgow, Renfrewshire, Port Glasgow 41151
Branches: London, CHAncery 4971 · Glasgow, Central 6208 · Manchester, Central 7904 Newcastle-upon-Tyne, Newcastle 26867 · Leeds, Leeds 30867 · Liverpool, Central 0230 Wolverhampton, Wolverhampton 21912 · Nottingham, Nottingham 42403 · Bristol, Bristol 21701 · Southampton, Southampton 23328.

SW/67

Circle **No 92** on reply card for further details

18/8 Titanium

(LOW COBALT) Stainless Steel Wire

Stainless Steel Wire, to this specification, is already being supplied by us in ever increasing quantities to meet the specific requirements of Nuclear Engineers and Designers. We shall welcome your enquiries for this and all other types of Austenitic Stainless Steel Wire.

Stainless Steel Wire Company Limited

THE BARRACKS · LANGSETT RD
SHEFFIELD 6

Telephone No.: 344241-2 Sheffield
Telegrams: Finewyre · Sheffield

PNEUTOMATION

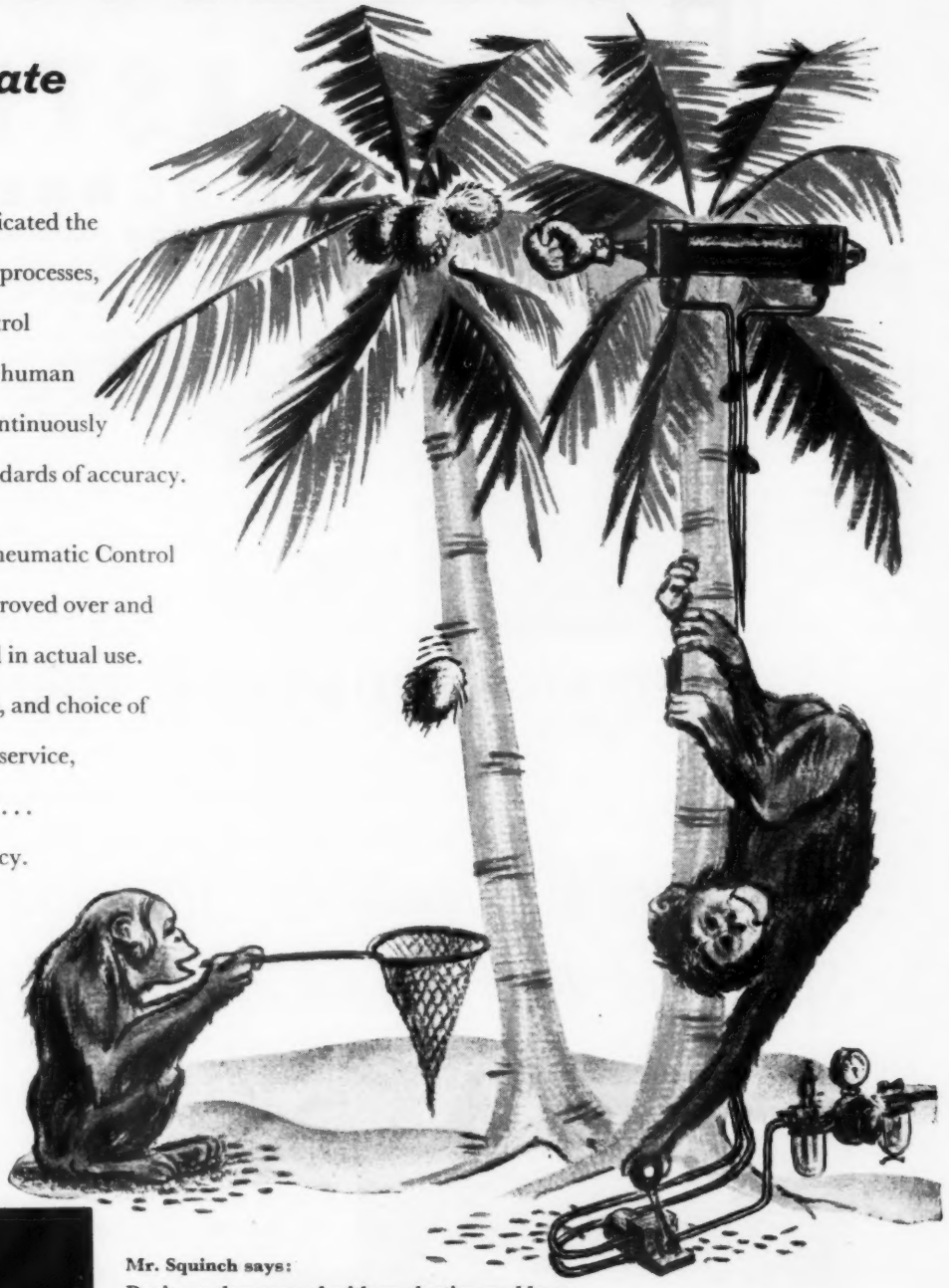
for accurate control

No matter how complicated the sequence of industrial processes, Lang Pneumatic Control equipment eliminates human error, and operates continuously to predetermined standards of accuracy.

Every item of Lang Pneumatic Control equipment has been proved over and over again in tests and in actual use. Design, workmanship, and choice of materials ensure long service, freedom from trouble . . . and consistent accuracy.

PNEUTOMATION
CANNOT FORGET

PNEUTOMATION—
ENERGY UNDER
CONTROL



Mr. Squinch says:
Don't monkey around with production problems:
consult Lang Pneumatic.

Write to:

Lang Pneumatic Ltd

(ASSOCIATED WITH DESOUTTER BROTHERS (HOLDINGS) LTD)

OWEN ROAD · WOLVERHAMPTON

Tel: Wolverhampton 25221/2/3/4
Telex No. 33193

P3642

Circle **No 93** on reply card for further details

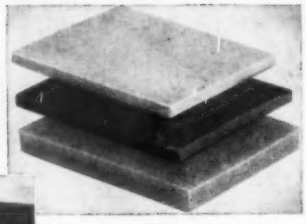
Circle **No 94** on reply card for further details

PRESCOLASTIK
REGD.

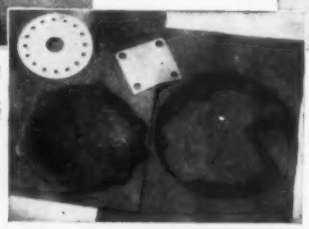
SILICONE RUBBERS

The most comprehensive range available

B. Prescolastik Silicone Rubber Sheet
Uses: Gaskets, Seals, Diaphragms, Washers, Etc.



A. Prescolastik Expanded Silicone Rubber
Uses: Soft Gasketing, Vibration Damping, Seals, Pads and Dampers.



C. Prescolastik Silicone Coated Fabrics
Uses: Diaphragms, Gaskets, Seals, Tapes, Ductings and Flexible Low Temperature Coverings.

TAKE ADVANTAGE of the technical resources and production facilities of the most modern silicone rubber plant in the United Kingdom.

Prescolastik silicone rubbers offer the widest available range of compounds to meet the most exacting conditions.

General Purpose Grades
Low Temperature Grades
Low Compression Set
Fuel and Oil Resistant Grades
Silicone Coated Fabrics
High Tensile Grades
High Temperature Grades
H.T.P. Resistant Grades
Cellular Rubbers

Designers and Engineers are invited to write to us for technical data.

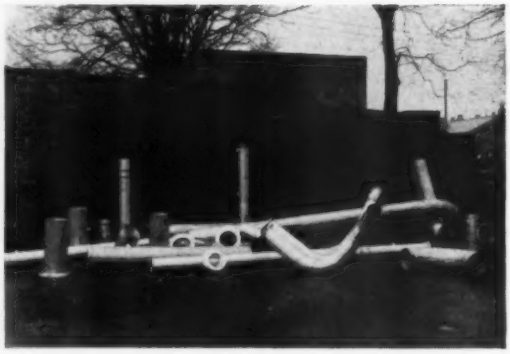
Specialists in precision rubber engineering

PRECISION RUBBERS LIMITED

BAGWORTH, LEICESTER, ENGLAND

Telephone: Bagworth 361 (six lines)

Specialists in Aluminium Alloy Plate and Structural Fabrications of all descriptions



Heat Exchangers
Pressure Vessels
Structural Aluminium of all descriptions
Smooth bore pipes and fittings up to 24" diameter

Your enquiries would receive our immediate attention

Illustrated is an 8" and 12" Bore Pipe installation fabricated for the Ministry of Supply

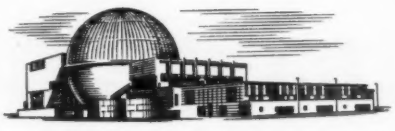
One of the first users of the Argon Arc welding process in the country, we again lead in the installation of the Sigmette Fine Wire welding equipment which opens a new field in the welding of Aluminium and its alloys, Non-Ferrous metals and Stainless Steels

E. C. PAYTER & CO. LIMITED

MEETING ST., GREAT BRIDGE, TIPTON, STAFFS. *Tel.:* TIPTON 2121

BY APPOINTMENT TO HER MAJESTY THE QUEEN
Suppliers of Fire Extinguishers *The Pyrene Company Limited*

facing new industrial fire problems



The Pyrene Company, with its unrivalled facilities for research, keeps ahead of changing industrial techniques, and is constantly developing the means to overcome the new fire risks they involve. As makers of the world's most comprehensive range of fire-fighting equipment, The Pyrene Company can give you invaluable and impartial advice on any fire protection problem—it is yours for the asking. We are proud to have given advice on fire protection—and supplied major fire-fighting equipment—for most British atomic centres already constructed. This service is also being applied to many new engineering plants and production methods used in modern industry. Consult Pyrene Fire Engineers and ensure maximum fire protection for valuable plant and human lives too.

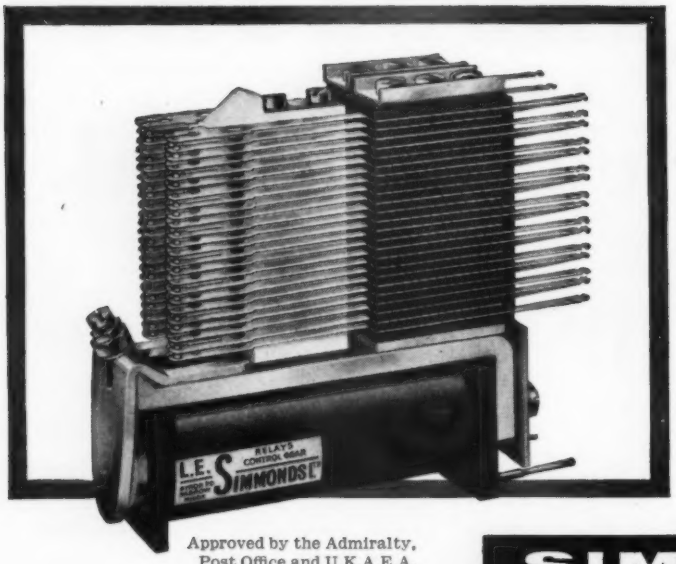
Pyrene TRADE MARK FIRE APPLIANCES
protect
ALDERMASTON
CALDER HALL
CAPENHURST
DOUNREAY · FOULNESS
HARWELL · SPRINGFIELD
WINDSCALE

Pyrene TRADE MARK FIRE FIGHTING EQUIPMENT

THE PYRENE COMPANY LIMITED
(*Dept. NP 10*) 9 GROSVENOR GARDENS · LONDON S.W.1 *Tel:* VICtoria 3401
Head Office & Works: GREAT WEST ROAD · BRENTFORD · MIDDX
Canadian Plant: TORONTO *Australian Plant:* MELBOURNE

Circle **No 97** on reply card for further details

Relays to specification



POST OFFICE TYPE 3,000 AND 600 RELAYS

A NEW DEVELOPMENT—illustrated here is our P.O. Type 3,000 Relay with ***sixteen*** changeovers with Light Duty Silver or Platinum Contacts. **P.O. TYPE 600 RELAYS** with Heavy Duty Contacts rated at 8 amps. also available. Complete range of both types manufactured to specification. Prototypes 24 hours. **P.T.F.E.** insulation now available. Specialists in **TROPICAL FINISHES.** Guaranteed to full **A.I.D.** and **I.E.M.E.** standards.

Approved by the Admiralty, Post Office and U.K.A.E.A. All relays guaranteed made in our own works.

SIMMONDS

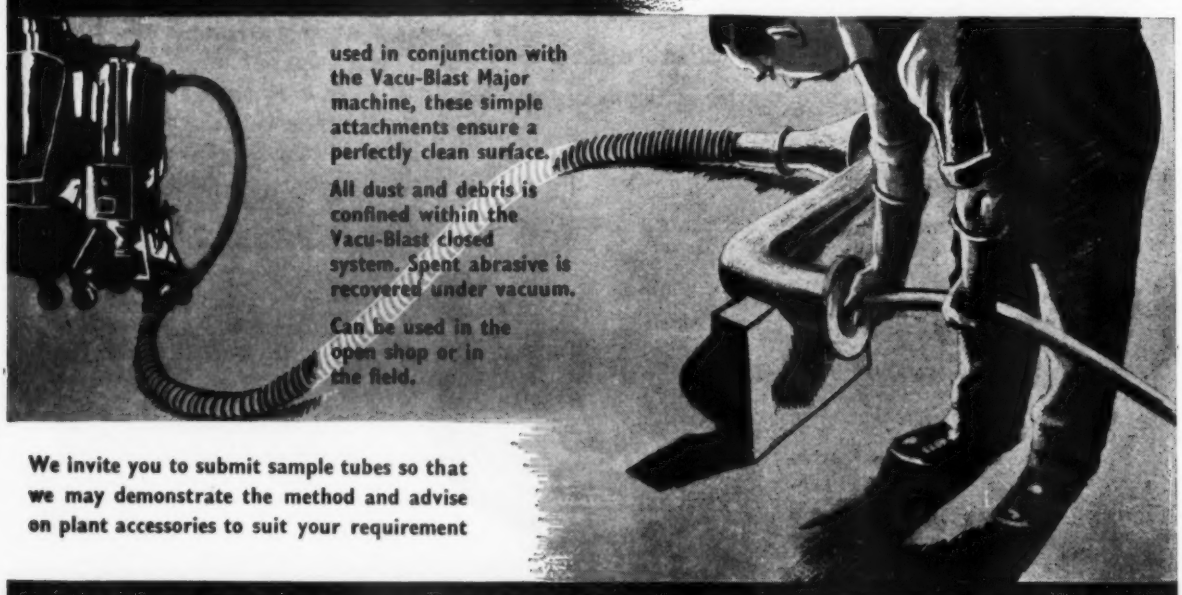
Manufacturers to H.M. Government Departments and leading Contractors.

L. E. SIMMONDS LTD., 5, BYRON ROAD, HARROW, MIDDX. TEL: HARROW 7797/9 TELEGRAMS: SIMRELAY HARROW

VACU-BLAST

for shot blasting tubes of any size from $\frac{1}{8}$ inch bore upwards

the only effective way to remove scale, fused sand and corrosion products from the internal surface of tubes of practically any shape or size.



used in conjunction with the Vacu-Blast Major machine, these simple attachments ensure a perfectly clean surface.

All dust and debris is confined within the Vacu-Blast closed system. Spent abrasive is recovered under vacuum.

Can be used in the open shop or in the field.

We invite you to submit sample tubes so that we may demonstrate the method and advise on plant accessories to suit your requirement

VACU-BLAST LIMITED, BATH ROAD, SLOUGH, BUCKS, ENGLAND.

TELEPHONE : SLOUGH 24507/9

4PAF

Over a Ton

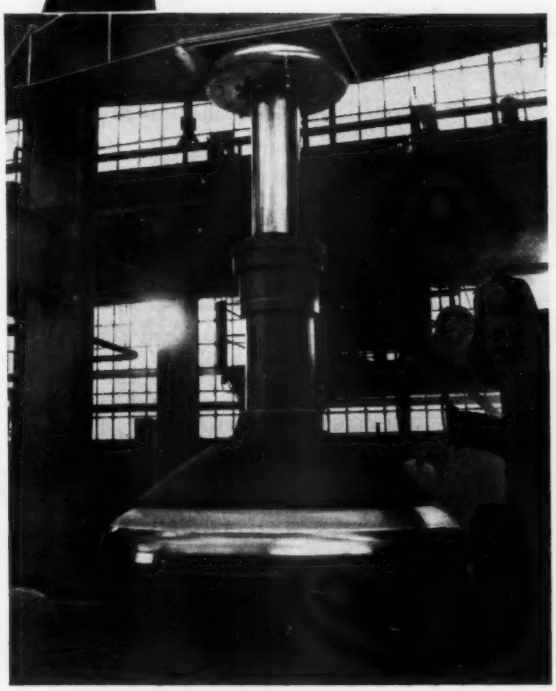
of Aluminium Alloy spun to 10 ft. i/d x $1\frac{5}{8}$"

One of a number produced for pressure vessels to hold liquid air, this 10 ft. aluminium end was spun by Harveys on the Rotarpress. The 12 ft. flat discs needed for spinning these ends, which are believed to be the largest spun aluminium ends produced in this country, were formed by butt-welding two plates of aluminium alloy together.

The Rotarpress is one of the large-capacity units in Harveys Heavy Fabrication Department. It produces ends up to 15 ft. diameter and is adaptable over a wide range of knuckle radii and depths.

The contours of semi-ellipsoidal ends produced by the spinning process enable plate thickness to be reduced, and in most cases tool costs are eliminated. Enquiries are invited for ends only or for complete

FABRICATION OF PRESSURE VESSELS.



HARVEY

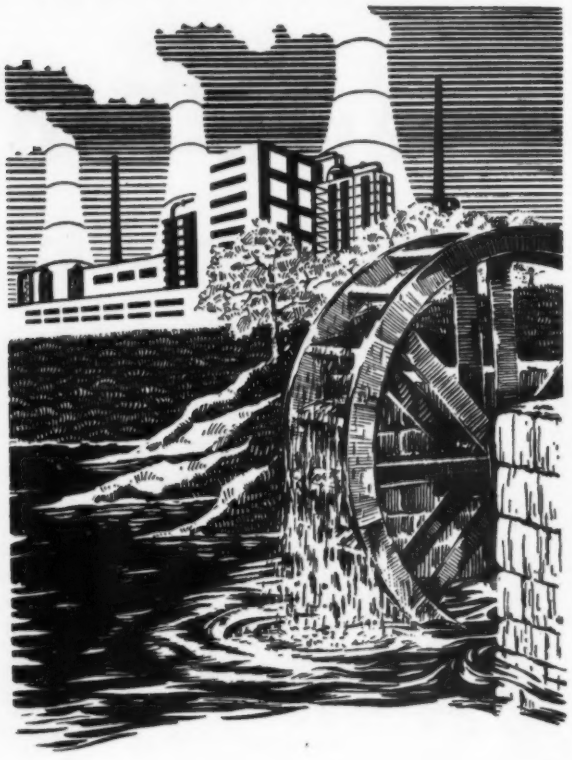
G. A. HARVEY & CO. (LONDON) LTD.

Woolwich Road, London, S.E.7. GREenwich 3232 (22 lines)

Other Harvey facilities: FABRICATIONS UP TO 120 TONS IN ONE PIECE · HEAVY MACHINING AND FITTING · HEAT TREATMENT AND RADIOGRAPHY · STEEL PLATE AND SHEET METALWORK · PERFORATED METALS · WOVEN WIRE · WIREWORK HH/7

Circle **No 99** on reply card for further details

Circle **No 100** on reply card for further details



WATER

is still in the foreground...

However revolutionary the methods of producing power may become, water is still all-important; and the need to give complete and lasting internal protection to water tanks in modern plants remains paramount.

With a reputation consolidated over 30 years of successful use **BITOTES Solution and Enamel** prevents interior corrosion of all steel and concrete water containers and conduits. BITOTES cannot crack or peel and is tasteless and odourless when dry. It is fully approved for Fresh Water, Drinking Water, Demineralised Water, etc.

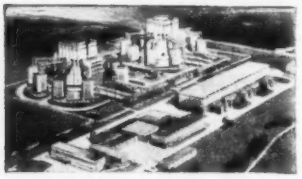
May we send you details

BITULAC LIMITED
(PAINTS DIVISION)

Collingwood Buildings, Newcastle upon Tyne, 1.
London Office: 189/190 Temple Chambers, Temple Avenue, London, E.C.4

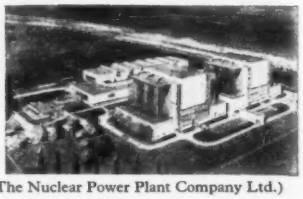
Circle **No 101** on reply card for further details

ad



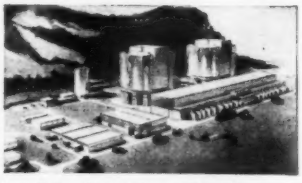
BERKELEY
(A.E.I.—John Thompson Nuclear Energy Co. Ltd.)

in



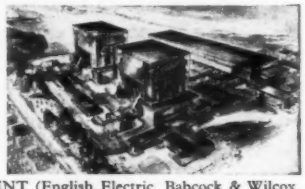
BRADWELL (The Nuclear Power Plant Company Ltd.)

fi



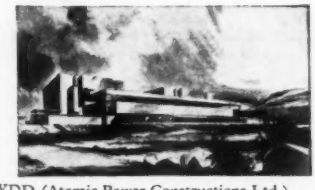
HUNTERSTON (G.E.C.—Simon-Carves Group)

ni



HINKLEY POINT (English Electric, Babcock & Wilcox, Taylor Woodrow Atomic Power Group)

tum

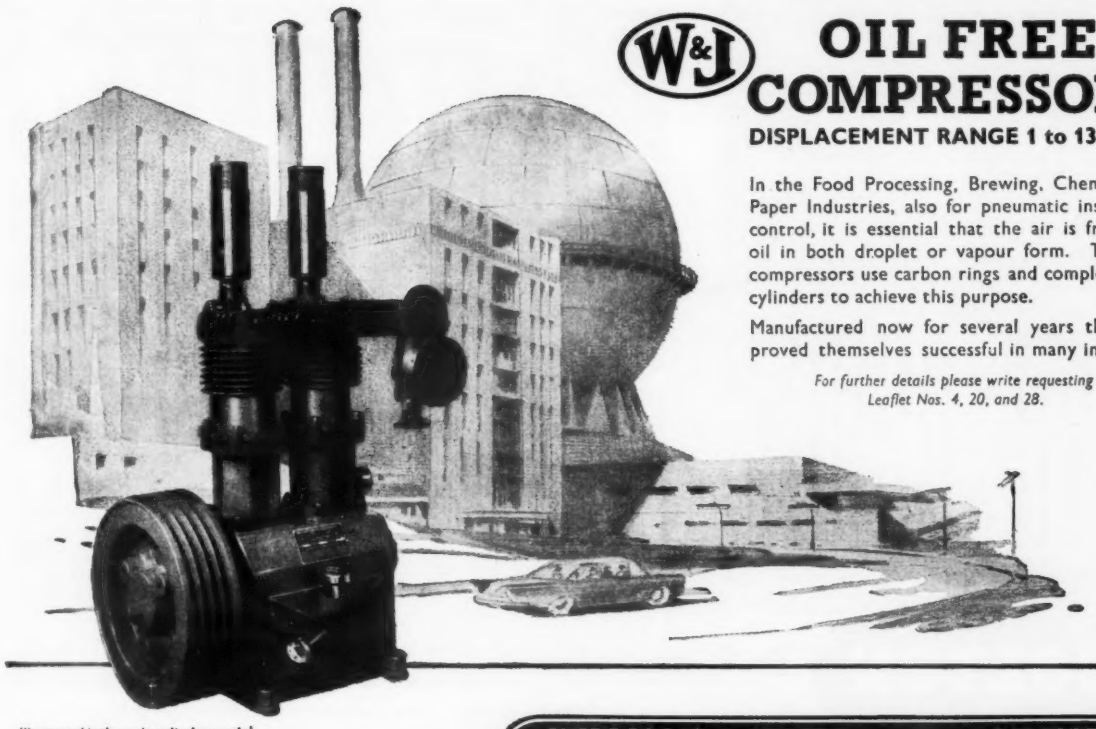


TRAWSFYNYDD (Atomic Power Constructions Ltd.)
(An impression by Mr. Basil Spence, Consultant Architect to Nuclear Civil Constructors, showing how the design blends into the landscape of Snowdonia)

Vokes Genspring constant support hangers — capable of supporting loads up to 97,800 lbs and travels up to 12"—have been specified by all five members of the Nuclear Consortia for each of the first five Nuclear Power Stations. Gensprings have already been installed at Calder Hall A & B and Chapel Cross A & B where their success in handling the movement of piping caused by temperature changes is rapidly making them an automatic choice for pipework support in the construction of Nuclear Power Stations.

Vokes Genspring SUSPENSION SYSTEMS
VOKES GENSPRING LIMITED
GUILDFORD · SURREY
Telephone: Guildford 62861 (6 lines) Telex: 8 -535 Vokesacess, Guildford.
Telegrams & Cables: Vokesacess, Guildford, Telex.
A member of the VOKES Group
VG46

Circle **No 102** on reply card for further details



W&J

OIL FREE COMPRESSORS

DISPLACEMENT RANGE 1 to 136 c.f.m.

In the Food Processing, Brewing, Chemical and Paper Industries, also for pneumatic instrument control, it is essential that the air is free from oil in both droplet or vapour form. The W&J compressors use carbon rings and completely dry cylinders to achieve this purpose.

Manufactured now for several years they have proved themselves successful in many industries.

For further details please write requesting Leaflet Nos. 4, 20, and 28.

Illustrated is the twin cylinder model having a free air delivery of 50 c.f.m.

WILLIAMS & JAMES (ENGINEERS) LIMITED
GLOUCESTER · ENGLAND
TELEPHONE: GLOUCESTER 24021-2-3 · TELEGRAMS & CABLES: "COMPRESSOR GLOUCESTER"

ASTRONOMICAL ACCURACY

By courtesy of the Mount Wilson and Palomar observatories

NEW 74 INCH REFLECTING TELESCOPE

This large Telescope manufactured by the Sir Howard Grubb Parsons Company, is for the Okayama Astrophysical Observatory which is a branch of the Japanese Tokyo Astronomical Observatory, and will be one of the largest ever to be erected in Asia.
The main optical component, a parabolic glass mirror, collects light from distant stars and focuses it either on to a photographic plate or on to a slit of the spectroscope. The mirror weighs about 11 tons and is 74 inches in diameter.
Fifty tons of complex mechanisms can be put into motion by push button control and direct the Telescope with such precision that a star image of no more than one thousandth of an inch is produced, and then held steady on the photographic plate to less than one thousandth of an inch for some hours. This is equivalent to a pointing accuracy of an orange 20 miles away.

176 HOFFMANN BEARINGS AND 300 HOFFMANN STEEL BALLS *CONTRIBUTE TO THIS ACCURACY*

The Hoffmann Manufacturing Company have supplied the main Polar Axis bearings and many smaller bearings on other moving parts of the Telescope. The diversity of these applications amply justifies our claim for the suitability, efficiency and dependability of Hoffmann bearings.

THE HOFFMANN MANUFACTURING CO. LTD., Chelmsford, Essex
TELEPHONE: 3151 (SEVEN LINES) TELEX No. 1951

MANUFACTURERS OF PRECISION BALL AND ROLLER BEARINGS WITH A LONG STANDING TRADITION OF QUALITY. EST 1898

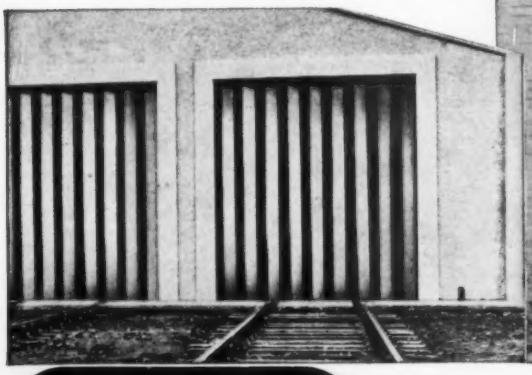
Circle **No 103** on reply card for further details

Circle **No 104** on reply card for further details

BOLTON Patent Shutter Doors

Custom built to your requirements

Available with continuous glazing, as shown on right, Bolton Shutter Doors readily accommodate all special requirements from railway track clearance, as shown below, to overhead cables and runway beams. May we send you our latest catalogue, reference NP 346?



BOLTON *The BIG name in doors*

BOLTON GATE CO LTD
BOLTON · LANCASHIRE

Branches in London, Glasgow, Birmingham and towns throughout the country

BG346

Make Datum *your starting point*

★ Well-proved design.

★ Up-to-date folded section construction.

★ Rack tappings to suit British, U.S. and Continental equipment.

★ Identical front and rear frames.

★ Unit doors of *any* size on front or rear.

★ Cooling by blower, extractor fan or natural convection *without modification to rack.*

Datum **RACKS**

are engineered to your requirements

In the finest quality zinc-coated steels and finished in high-relief hammer stove enamel; other finishes available to your own particular specification.

Delivery period for most standard Racks is seven days.

Datum **METAL PRODUCTS LTD.**

COLNE WAY TRADING ESTATE · WATFORD-BY-PASS
WATFORD · HERTS
Telephone: Watford 22351 Telegrams: Datum, Watford

A member of JLT GROUP

Circle **No 106** on reply card for further details

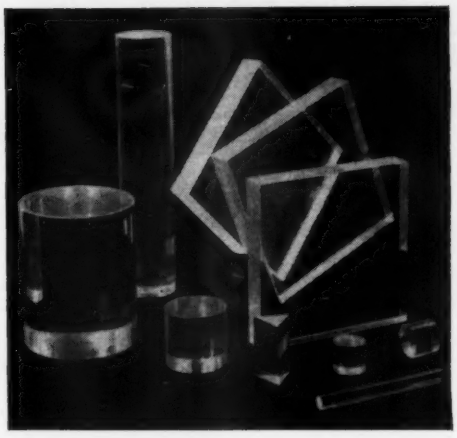
A Complete Scintillation Service

phosphors and counters

PLASTIC AND LIQUID PHOSPHORS

- PLASTIC PHOSPHOR NE 102, light output 65% anthracene, available in all sizes and shapes up to one ton, in thin sheet form, in fine tubes for the construction of scintillation flow counters, or as filaments for the construction of scintillation nuclear track chambers.
- BORON POLYESTER PLASTIC PHOSPHOR NE 400 and NE 401 (88% B^{10}) for neutron detection. Standard sizes from 0·5 to 5·0 inches diameter.
- SCINTILLATION CHEMICALS of highest purity P.B.D., POPOP, T.P.B., p-terphenyl, PPO, D.P.H., alpha-N.P.O., D.M.C., B.B.O., B.P.O., D.P.A., D.P.S., vinyltoluene, styrene, xylene, toluene, methyl borate, phenylcyclohexane, monoisopropylbiphenyl.
- SCINTILLATION CRYSTALS by Harshaw. Exclusive concessionaire in Great Britain for NaI(Tl), CsI(Tl), LiI(Eu), and Li^6I(Eu). NaI(Tl) available in sizes up to 9" diameter × 9" thick, and down to 0·015" thick with 0·005" Be windows for X-ray counting and spectrometry. Resolution with standard sizes 7–8% on Cs^{137} line. CsI(Tl) down to 0·005" thick for alpha and proton studies. Li^6I(Eu) in special low temperature mounts for fast neutron spectrometry.
- NEW! Photomultiplier—NaI(Tl) combinations with direct coupling of crystal to photomultiplier and giving improved resolution.
- LIGHT PIPES.
- SPIRAL FLOW CELL NE 801.
- SCINTILLATING GELS.
- LOADED LIQUID SCINTILLATORS.

Write for Bulletins and Price List.



PRECISION NUCLEAR INSTRUMENTS

- Non-overloading Linear Pulse Amplifier NE 5202 of the Fairstein type.
- Pre-Amplifier and Cathode Follower NE 5202A.
- Single Channel Pulse Height Selectors NE 5102 and NE 5103.
- Shielded Scintillation Head Units NE 5501-3.
- Highly Stabilised EHT Supplies NE 5302 (1·5 kV) and NE 5303 (5 kV).
- Complete assembly for C14 and tritium counting NE 8301.
- Complete Human Body Monitors and low-level counting facilities.
- Ratemeter NE 5401 with six ranges and five time constants.
- Scanning scintillation spectrometer NE 8601.
- C.D.C. 100 Channel Transistorized Kick-sorter.

Nuclear Enterprises (G.B.) Ltd

BANKHEAD MEDWAY, SIGHTHILL, EDINBURGH, 11
SCOTLAND — Tel: CRA 5262

Associate Company: Nuclear Enterprises Ltd., 1750, Pembina Highway, Winnipeg, Canada.

14

high vacuum equipment

WRITE NOW FOR THE TRADE'S MOST HELPFUL CATALOGUE

The newest re-issue of the N.G.N. Catalogue illustrates and describes a whole range of equipment especially designed and manufactured for the High Vacuum Industry....and which is already approved and used by leading high-vacuum engineers all over the world. N.G.N.'s special, highly-expert design combined with their new manufacturing techniques result in a range of components and equipment which are unique in their efficiency, adaptability and convenience.

Write NOW for the *new* N.G.N. Catalogue No. 881/20.

N.G.N. ELECTRICAL LIMITED

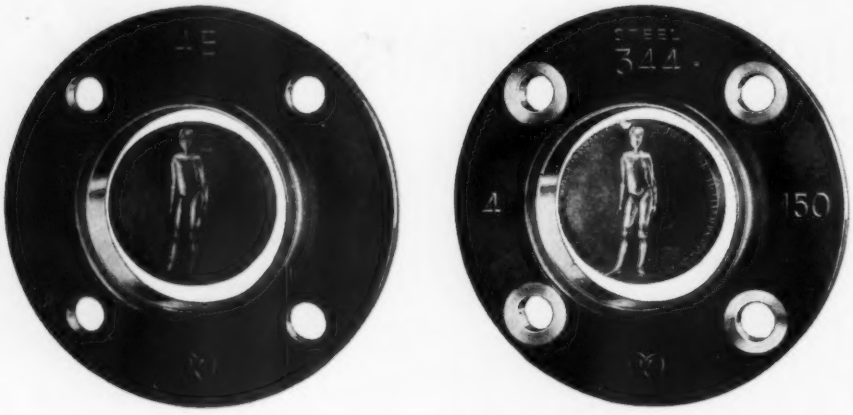
AVENUE PARADE,
ACCRINGTON, LANCS.
Telephone: Accrington 35611-2

ROTARY PISTON PUMPS
DIFFUSION PUMPS
BAFFLE VALVES
LOW TEMPERATURE TRAPS
COMBINED PUMPING UNITS
HAND OPERATED VALVES
ELECTRO MAGNETIC VALVES
COUPLINGS & UNIONS
VACUUM MEASURING EQUIPMENT
NYGON SEAL MATERIAL

Circle **No 107** on reply card for further details

Circle **No 108** on reply card for further details

The eyes of the World...



are on K FLANGES

TRADE MARK

SPECIFY BUY AND USE THE WORLD'S BEST FLANGES FROM

The only flanges to be awarded a silver and bronze medal at the World's Fair, Brussels

KIRK'S *other products included in the award are* Malleable Fittings, Fabricated Pipework, Welding Fittings, Welded and Seamless Steel Tubes and Fittings, Malleable Iron Castings, Drop Forgings, Valves, In Steel and Stainless Steel.

KIRK & CO. (TUBES) LTD.

74/92 PARADISE ST · LONDON · S.E.16 · BERMONDSEY 3156/7/8
and at MANCHESTER · WALSALL · PONTYCLUN

the 'AIKEN'

Low Pressure Valve

- FULL CLEAR BORE
- TEST PRESSURE TIGHT IN EITHER DIRECTION
- GREASE LUBRICATED SEATING
- TOROIDAL SEAL FOR SPINDLE
- FLANGES DRILLED TO B.S. 10 TABLES 'A' - 'E' INCLUSIVE
- INTERNAL SCREW WITH OR WITHOUT INDICATOR
- STANDARD ROTATION CLOCKWISE TO CLOSE

3" to 6" Sizes	8" to 12" Sizes
Working Pressures up to 20 p.s.i.g.	Working Pressures up to 15 p.s.i.g.
Standard Body Test 70 p.s.i.g. Hydraulic.	Standard Body Test 50 p.s.i.g. Hydraulic.
Standard Seat Test 30 p.s.i.g. Air.	Standard Seat Test 22½ p.s.i.g. Air.

THE BRYAN DONKIN COMPANY LTD.
CHESTERFIELD TEL: 3153 · LONDON TEL: ABBEY 1096

SERVICE DE RENSEIGNEMENTS POUR NOS LECTEURS

Il est souvent difficile au client publicitaire d'indiquer dans un espace restreint tous les détails de ses produits. Dans le cas où vous désireriez de plus amples renseignements à ce sujet, veuillez pointer le numéro approprié sur la carte ci-contre et envoyer cette dernière à NUCLEAR POWER

AUSKUNFTSDIENST FÜR LESER

Es ist oft schwierig für Inserenten alle technischen Einzelheiten über ihre Produkte in einem begrenzten Platz zu bringen. Sollten Sie noch weitere Auskünfte wünschen, streichen Sie einfach die bestimmten Nummern auf der nebenstehenden Karte an, und senden Sie sie an NUCLEAR POWER

SERVIZIO D'INFORMAZIONI PER I NOSTRI LETTORI

E' talvolta difficile all'inserzionista di indicare in uno spazio ristretto tutti i particolari dei suoi prodotti. Qualora desideraste ricevere più ampie informazioni a questo riguardo, favorite segnare il numero appropriato sul cartellino qui accanto ed inviare quest'ultimo a NUCLEAR POWER

SERVICIO DE INFORMACIÓN PARA EL LECTOR

Se hace a menudo difícil para los anunciantes dar en un espacio limitado todos los detalles técnicos sobre sus productos. Si desea ulterior información, marque los números apropiados en la tarjeta opuesta y mándela a NUCLEAR POWER

Информация для читателей

Часто бывает трудно рекламирующим лицам давать все технические подробности своей продукции в рекламе. Если Вам понадобятся добавочные сведения, то просто отметьте соответствующие номера на карточке на противоположной стороне и отправьте в NUCLEAR POWER

讀者詢問服務

在廣告上以有限的地方來解釋一些專门技術 及它們的効果 的確是有受限制的困难 若讀者欲要知道一些詳細的情形就請將对頁的表格 取一號下來將圈下有疑問的項目 寄回給一下郵寄條子能工經忠即可.

讀者サービス

廣告紙面の関係上製品の技術的細目は掲載しきれませんので詳しくは裏のカードの通番なナンバーに印をつけて原子力宛投函して下さればお答へします.

Nuclear Power
REACTORS MATERIALS INSTRUMENTATION PROCESSES IRRADIATION

READER INFORMATION SERVICE October 1960

Advertisements

1	24	47	70	93	116	139	162	185
2	25	48	71	94	117	140	163	186
3	26	49	72	95	118	141	164	187
4	27	50	73	96	119	142	165	188
5	28	51	74	97	120	143	166	189
6	29	52	75	98	121	144	167	190
7	30	53	76	99	122	145	168	191
8	31	54	77	100	123	146	169	192
9	32	55	78	101	124	147	170	193
10	33	56	79	102	125	148	171	194
11	34	57	80	103	126	149	172	195
12	35	58	81	104	127	150	173	196
13	36	59	82	105	128	151	174	197
14	37	60	83	106	129	152	175	198
15	38	61	84	107	130	153	176	199
16	39	62	85	108	131	154	177	200
17	40	63	86	109	132	155	178	201
18	41	64	87	110	133	156	179	202
19	42	65	88	111	134	157	180	203
20	43	66	89	112	135	158	181	204
21	44	67	90	113	136	159	182	205
22	45	68	91	114	137	160	183	206
23	46	69	92	115	138	161	184	207

New Products and Ind. Literature

208	214	220	226	232	238	244	250	256
209	215	221	227	233	239	245	251	257
210	216	222	228	234	240	246	252	258
211	217	223	229	235	241	247	253	259
212	218	224	230	236	242	248	254	260
213	219	225	231	237	243	249	255	261

Books

262	264	266	268	270	272	274	276	278
263	265	267	269	271	273	275	277	279

If you would like further information about any advertisement or editorial item, simply circle the appropriate numbers on this card and mail to NUCLEAR POWER.

NAME

NAME OF BUSINESS

ADDRESS

POSITION HELD

NATURE OF BUSINESS

Nuclear Power
REACTORS MATERIALS INSTRUMENTATION PROCESSES IRRADIATION

READER INFORMATION SERVICE October 1960

Advertisements

1	24	47	70	93	116	139	162	185
2	25	48	71	94	117	140	163	186
3	26	49	72	95	118	141	164	187
4	27	50	73	96	119	142	165	188
5	28	51	74	97	120	143	166	189
6	29	52	75	98	121	144	167	190
7	30	53	76	99	122	145	168	191
8	31	54	77	100	123	146	169	192
9	32	55	78	101	124	147	170	193
10	33	56	79	102	125	148	171	194
11	34	57	80	103	126	149	172	195
12	35	58	81	104	127	150	173	196
13	36	59	82	105	128	151	174	197
14	37	60	83	106	129	152	175	198
15	38	61	84	107	130	153	176	199
16	39	62	85	108	131	154	177	200
17	40	63	86	109	132	155	178	201
18	41	64	87	110	133	156	179	202
19	42	65	88	111	134	157	180	203
20	43	66	89	112	135	158	181	204
21	44	67	90	113	136	159	182	205
22	45	68	91	114	137	160	183	206
23	46	69	92	115	138	161	184	207

New Products and Ind. Literature

208	214	220	226	232	238	244	250	256
209	215	221	227	233	239	245	251	257
210	216	222	228	234	240	246	252	258
211	217	223	229	235	241	247	253	259
212	218	224	230	236	242	248	254	260
213	219	225	231	237	243	249	255	261

Books

262	264	266	268	270	272	274	276	278
263	265	267	269	271	273	275	277	279

If you would like further information about any advertisement or editorial item, simply circle the appropriate numbers on this card and mail to NUCLEAR POWER.

NAME

NAME OF BUSINESS

ADDRESS

POSITION HELD

NATURE OF BUSINESS

Nuclear Power
REACTORS MATERIALS INSTRUMENTATION PROCESSES IRRADIATION

READER INFORMATION SERVICE October 1960

Advertisements

1	24	47	70	93	116	139	162	185
2	25	48	71	94	117	140	163	186
3	26	49	72	95	118	141	164	187
4	27	50	73	96	119	142	165	188
5	28	51	74	97	120	143	166	189
6	29	52	75	98	121	144	167	190
7	30	53	76	99	122	145	168	191
8	31	54	77	100	123	146	169	192
9	32	55	78	101	124	147	170	193
10	33	56	79	102	125	148	171	194
11	34	57	80	103	126	149	172	195
12	35	58	81	104	127	150	173	196
13	36	59	82	105	128	151	174	197
14	37	60	83	106	129	152	175	198
15	38	61	84	107	130	153	176	199
16	39	62	85	108	131	154	177	200
17	40	63	86	109	132	155	178	201
18	41	64	87	110	133	156	179	202
19	42	65	88	111	134	157	180	203
20	43	66	89	112	135	158	181	204
21	44	67	90	113	136	159	182	205
22	45	68	91	114	137	160	183	206
23	46	69	92	115	138	161	184	207

New Products and Ind. Literature

208	214	220	226	232	238	244	250	256
209	215	221	227	233	239	245	251	257
210	216	222	228	234	240	246	252	258
211	217	223	229	235	241	247	253	259
212	218	224	230	236	242	248	254	260
213	219	225	231	237	243	249	255	261

If you would like further information about any advertisement or editorial item, simply circle the appropriate numbers on this card and mail to NUCLEAR POWER.

NAME

NAME OF BUSINESS

ADDRESS

POSITION HELD

NATURE OF BUSINESS

Postage will be paid by Nuclear Power

No Postage stamp necessary if posted in Great Britain or Northern Ireland

Business Reply Folder Licence WD 1823

NUCLEAR POWER
Rowse Muir Publications Ltd,
The Rowse Muir Building,
77–79 Charlotte Street,
London, W1
England

Postage will be paid by Nuclear Power

No Postage stamp necessary if posted in Great Britain or Northern Ireland

Business Reply Folder Licence WD 1823

NUCLEAR POWER
Rowse Muir Publications Ltd,
The Rowse Muir Building,
77–79 Charlotte Street,
London, W1
England

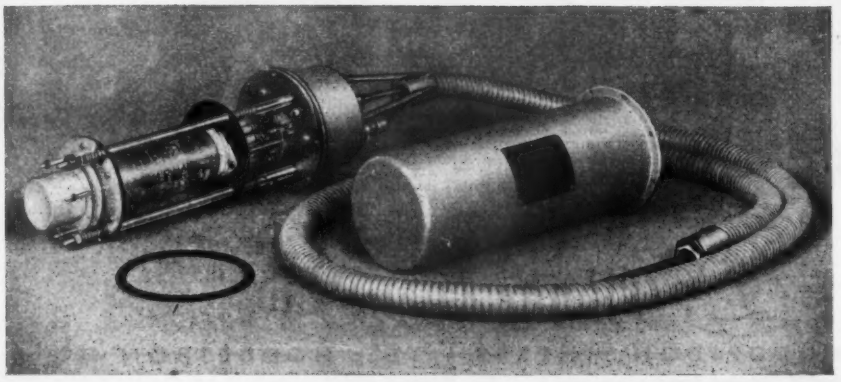
Postage will be paid by Nuclear Power

No Postage stamp necessary if posted in Great Britain or Northern Ireland

Business Reply Folder Licence WD 1823

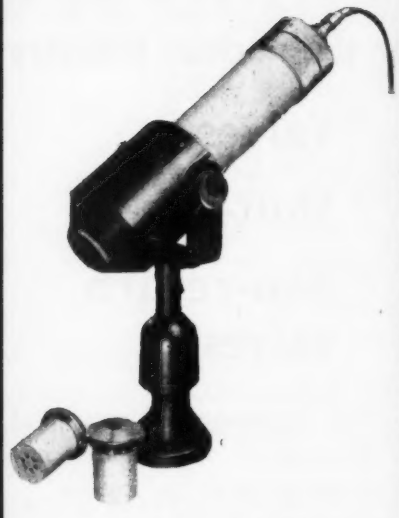
NUCLEAR POWER
Rowse Muir Publications Ltd,
The Rowse Muir Building,
77–79 Charlotte Street,
London, W1
England

TWO *Labgear* SCINTILLATION COUNTERS



TYPE D4132

A gamma - sensitive end - window scintillation counter specially designed for industrial applications.



TYPE D4133

A gamma-counting scintillation detector with variable directional characteristics designed essentially for medical applications.

Specially designed scintillation counters form part of the wide range of nucleonic and electronic instruments, designed and manufactured by Labgear Ltd., which are giving valuable service in industry and research. Both these counters reflect the most advanced techniques and are designed for maximum convenience in routine use.

TYPE D4132 The unit comprises a large thalium-activated sodium-iodide crystal optically coupled to an eleven-stage photomultiplier, and a cathode follower in a sealed container. Shock-proofing of the crystal-photomultiplier assembly is provided by adjustable spring tensioning between them. The outer screening case with end window forms a light-tight sealed enclosure when bolted to the bulkhead separating photomultiplier with dynode chain from the cathode follower. The scintillation counter may be located up to 100 ft. from associated equipment without unduly affecting its output characteristics, and the unit is suitable for use with the Labgear Recording Ratemeter D4124.

TYPE D4133 A thalium-activated sodium-iodide crystal is optically coupled to an eleven-stage multiplier contained within a brass casing with lead shielding and a thin aluminium end-window. To facilitate the interchange of phosphors the encapsulated crystal and light guide is retained against the face of the photo cathode by collets housed in the screen. When removed from the shielding, the crystal - multiplier - dynode - resistor chain may be used as an end-window detector. Provision is made for three interchangeable lead collimator inserts, enabling defined areas to be monitored or scanned, and depth of radiation maxima or minima to be determined. The instrument is designed for use with Clinical Ratemeter D4130 and Percentage Uptake Counter D4135, or for other ratemeters having a suitable photomultiplier collector load.

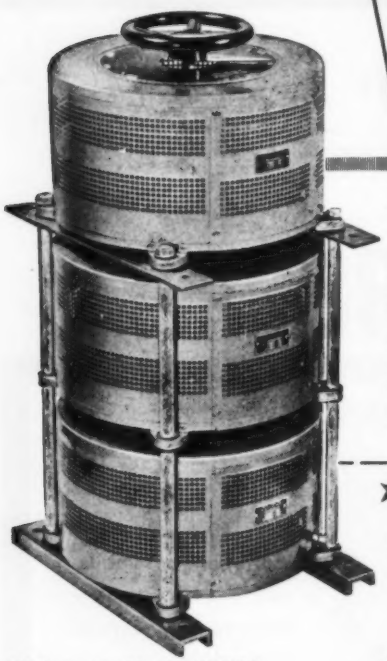
Labgear

LABGEAR LIMITED · WILLOW PLACE · CAMBRIDGE · ENGLAND

Telegrams: Labgear Cambridge Telephone: Cambridge 88022

Variac WITH Duratrak ☆

Regd. Trademark



This 3-gang assembly, Type 50-BMG3, will control 22·5kVA, 3-phase or single-phase according to connection. Larger assemblies can be made.

THE MOST USEFUL DEVICE KNOWN FOR THE CONTROL OF AC VOLTAGE

VARIAC is the original continuously-adjustable auto-transformer, providing a smoothly variable output from zero to line voltage and above.
VARIACS are available in a very wide range of models from small units for laboratory and instrument use to large ganged assemblies for three-phase power.
VARIACS are available open or covered, as single units or ganged assemblies, for manual operation or motor-driven.

The range includes portable, metalclad and oil-immersed models, dual-output types, high-frequency types and many 'specials'. *Write for complete information.*

This small Variac, Type V-5HMTF, provides an output of 0-270 V, 2 A, from 240 V 50 c/s mains. A still smaller model, Type V-3H is rated at 1 A.

☆ **Duratrak?** Duratrak (Regd. Trademark) — a patented* feature exclusive to Variac — is a special plated contact surface giving longer life, increased overload and surge capacity and maximum economy in maintenance. Duratrak is now standard on all models except Series 50.
*U.K. Pat. No. 693406

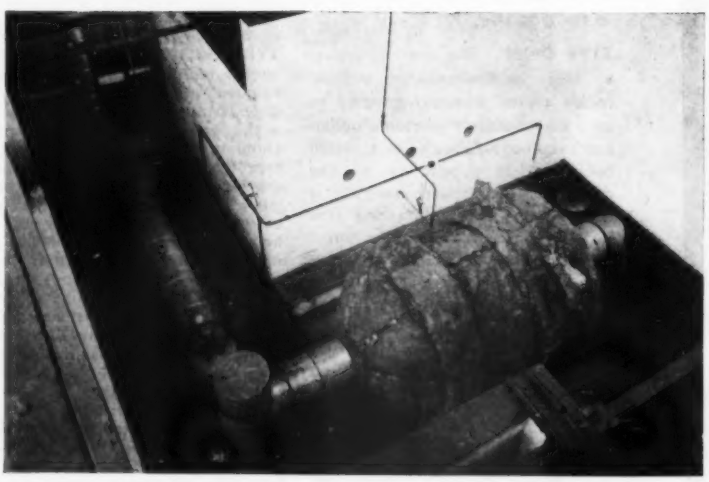
ONLY VARIAC HAS DURATRAK

Claude Lyons Ltd.

VALLEY WORKS · HODDESDON · HERTS · TEL: HODDESDON 4541-6
and 76 Old Hall Street · Liverpool 3 · Tel: CENtral 4641-2

CL 59/28

Jansen Brassfounding and finishing for the nuclear industry



- **Valves**
- **Shut-offs**
- **Non-return valves**

Flow regulation and shut-off at the highest temperatures and pressures for all applications.

Available with fully automatic control.

Th. Jansen S.A. — Rethel (Ardennes)

Tel: 390-391 RETHEL, Cable address: JANSEN RETHEL

Telex: JANSEN — RETHEL No NANCY 83070

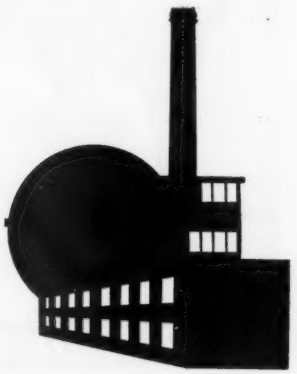
Circle **No 113** on reply card for further details

SPECIAL STEELS

FOR THIS MODERN AGE

ARE OUR BUSINESS

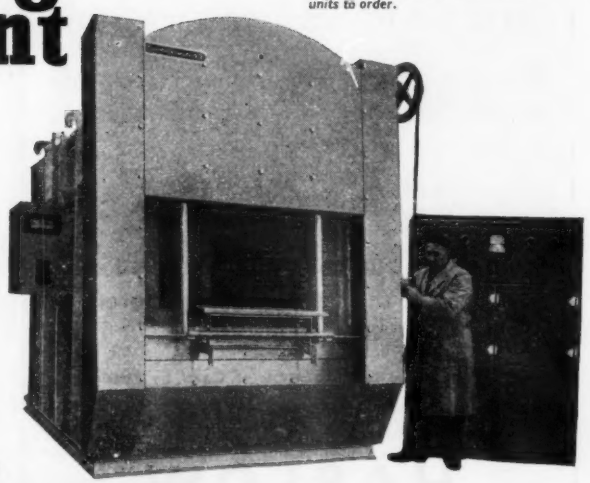
- STAINLESS STEELS
- HEAT RESISTING STEELS
- VALVE STEELS
- HIGH SPEED STEELS
- TOOL & DIE STEELS



C. G. CARLISLE & CO. LTD. IONA WORKS, PENISTONE ROAD, SHEFFIELD. *Telephone : 348791*

'B-W' Heat treatment processing equipment

A medium capacity heat-treatment furnace from the Barlow-Whitney range. Wide choice of standard models and, of course, custom-built units to order.



The 'Barlow-Whitney' comprehensive range supplies the answer to most industrial heating problems. Make use of the 'B-W' Technical Advisory Service —their long experience is at your disposal without obligation.

B-W PRODUCTS include—

FURNACES · PROCESSING OVENS
HUMIDITY CHAMBERS
MELTING POTS
HEATED AUTOCLAVES
FLOWLINE HEATERS

Write for further details quoting reference C1060

PROCESS HEATING

Barlow-Whitney

Tel: AMBassador 5485/6

BARLOW-WHITNEY LTD., 2 Dorset Square, London, N.W.1

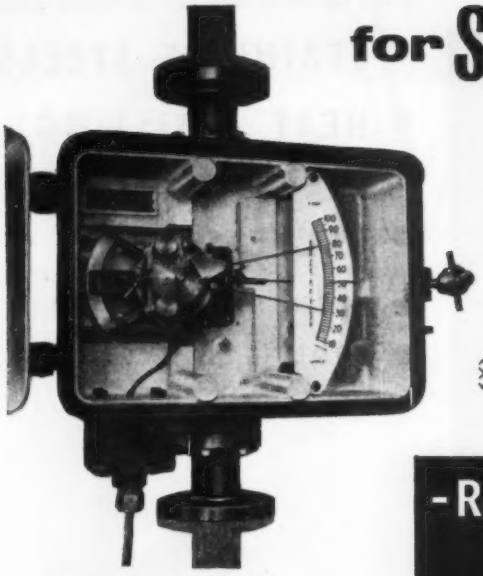
Works: London & Bletchley

BMJ

Circle **No 114** on reply card for further details

Circle **No 115** on reply card for further details

for SAFETY in your pipeline

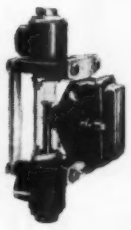


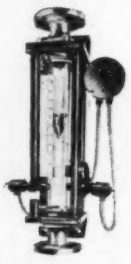
Where a change of liquid or gas flow rate is dangerous then one of these Rotameter flow alarms can be used to provoke attention. Electric or pneumatic signals provide visual or audible alarm.

For details of the instruments shown here, please write for leaflet NP.2010/24.

Type 500A
Electric or pneumatic signal, fully adjustable, for liquids or gases.

- Rotameter flow alarms





Type 750 **Metric Series** **Type 825A**

ROTAMETER
FLUID MEASUREMENT AND CONTROL
FLOW-DENSITY-LEVEL

ROTAMETER MANUFACTURING CO. LTD
330 PURLEY WAY, CROYDON, SURREY
Telephone : CROydon 3816

G.24

Circle **No 116** on reply card for further details

TIME CLOCK CARDS

TO FIT EVERY TYPE OF MACHINE
EXACTLY TO YOUR REQUIREMENTS

Our Time Cards are manufactured with extreme care and we guarantee them to be trouble free.

7 DAYS' DELIVERY — TOP QUALITY — LOW PRICE

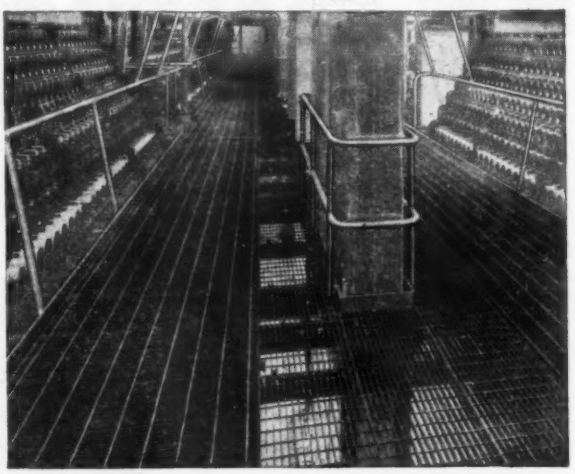
You cannot do better than by dealing direct with the largest manufacturers in the country.

We can quote for any type of Card by return:
Send us your samples today.

HARLOW

HARLOW PRINTING WORKS (NORTHERN) LTD.
104-110 FREDERICK STREET
SOUTH SHIELDS
Telephone : South Shields 4286 (3 lines)

Circle **No 117** on reply card for further details



Non-Slip **MECHANICALLY LOCKED No. 3 Type**

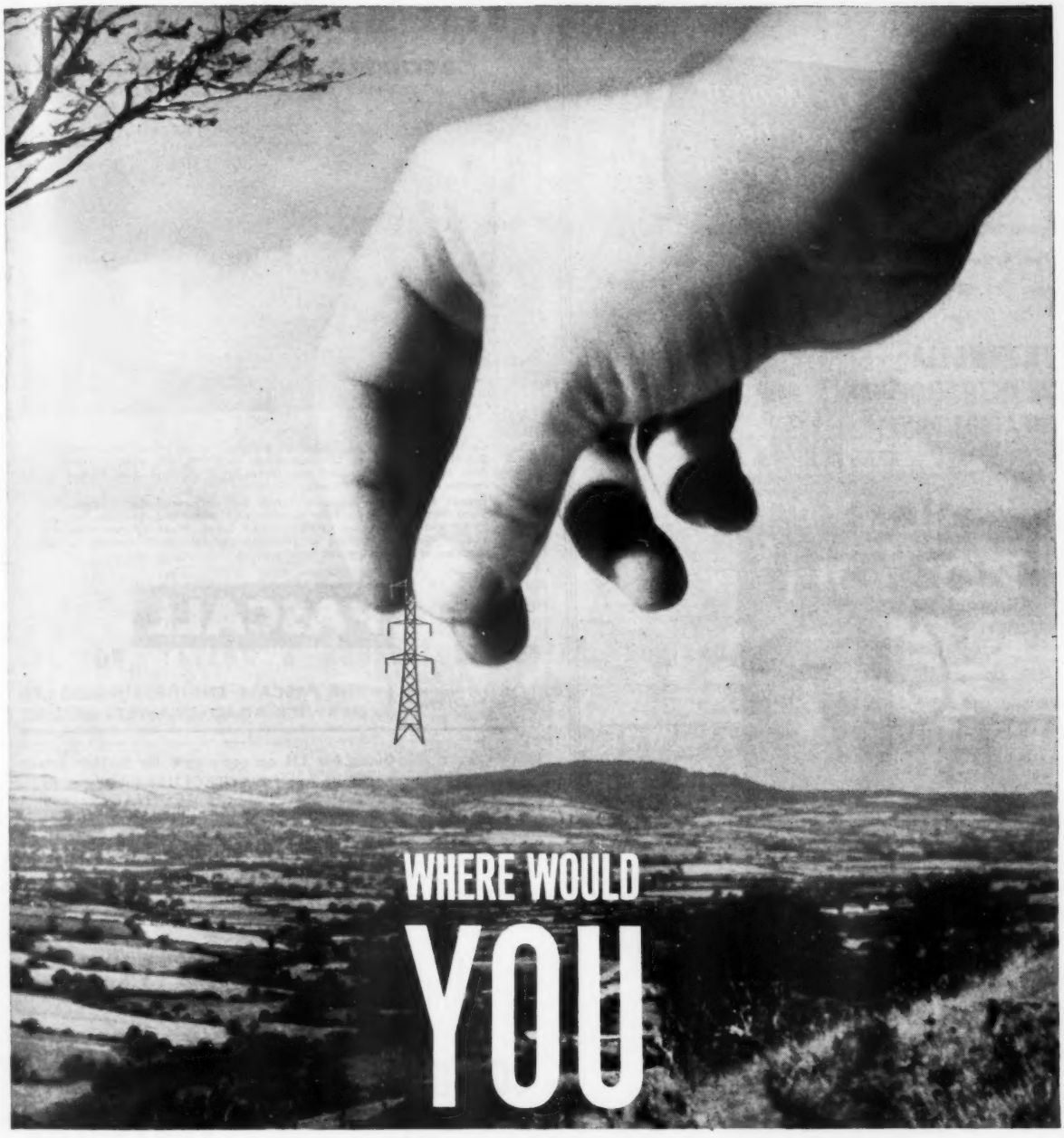
OPEN STEEL FLOORING

Ideal for factories, warehouses, refineries, gas works, fire escapes, etc.
Supplied with handrails and standards if desired.

by Bettles

Our technical staff will be pleased to assist you

BETTLES & SONS LTD., ARCWEL FACTORY
STAFFORD ROAD, FORDHOUSES, WOLVERHAMPTON
Telephone: Fordhouses 2278-9



RUN THE PYLONS?

They still live by lamp-light up in the hills. Soon, a new transmission line will thread its way along the valley, bringing the people up on the hill the electricity they've been wanting.

Pylons down here will mean a better life up there. But how will the people of the valley feel about the pylons? And the people who visit the valley?

The Central Electricity Generating Board are just as concerned about this as they are about bringing in the power. For the nation has charged the Board with a double duty. Not only to maintain an efficient, economical electricity supply, but also to preserve the amenities of the country as they go.

Often, these duties conflict. Again and again problems arise which seem impossible to solve. But always, they seek to achieve a balance. A balance between the need to answer demands for more power and the need to preserve the beauty, the intangible values, of a landscape, a village, the still unspoilt approaches to a town.

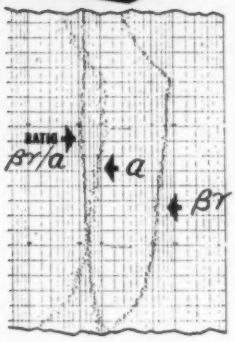
■ **These advertisements are appearing in the farming and country magazines. The Central Electricity Generating Board thank contractors for their co-operation in the past, and know that they will do all they can, while engaged on work for the Board, to preserve amenities.**

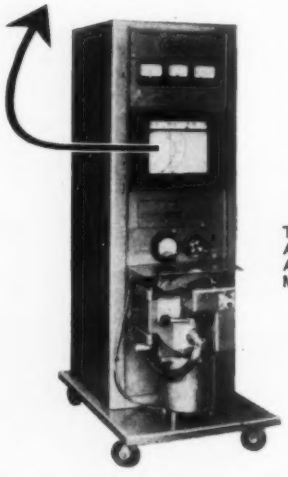
THE CENTRAL ELECTRICITY GENERATING BOARD

CEGB

Circle **No 119** on reply card for further details

This Air Monitor Solves the Natural Radon Progeny Problem





The New AM-33R Air Monitor

The AM-33R is First to Provide *Direct* Identification of Long Half-Life Emitters

Due to natural radon progeny, identification of long half-life emitters with ordinary monitors means a delay of five hours or more, and requires multiple detectors. Now, with the new AM-33R air monitor, the presence of these emitters can be identified directly, and almost immediately—with a single detector.

NMC

Nuclear Measurements Corp.

International Office:
13 E. 40th Street, New York 16, N.Y.

Circle **No 120** on reply card for further details

TEST SIEVES *for*
accurate particle size analysis

Complete range of all sizes of standard tests sieves conforming to B.S.410:1943 and to U.S. standards, A.S.T.M. Ell, readily available. Also special, non-standard test sieves with stainless steel frames and meshes or with nylon meshes.

Frames fitted with precision woven and uniformly taut meshes. One piece frame and spun fillet construction eliminates crevices between frame and mesh where particles could lodge. Made to nest one with another and to present a perfectly smooth inner surface to the particles of material under test.

PASCALL

Write or telephone Crawley 25166 for List SV3210

THE PASCALL ENGINEERING CO LTD
GATWICK ROAD · CRAWLEY · SUSSEX

Circle **No 121** on reply card for further details

Apply ELECTROLUBE lubricants to all SWITCH CONTACTS and BEARING SURFACES of turret tuners, plugs and sockets, controls, gram motors, tape recorders, etc.

ELECTROLUBE lubricants are a British discovery—a scientific preparation—not "just another switch cleaner".

ELECTROLUBE lubricants stay effective for months.

Make **contact** with *Electrolube* BRAND **LUBRICANT**

No. 1 22/- net trade
No. 2 33/- net trade

ELECTROLUBE Brand No. 1 for light current applications, reduces fixed and relay contact resistance, stops audio interference, increases h.f. and l.f. gain by 3 db., etc.

ELECTROLUBE Brand No. 2 for sparking contacts and heavier current duties, operates under difficult conditions, reduces wear on contactors 3 to 5 times; increases life of battery motors 8 times.

Available in New NYLON SNORKEL container

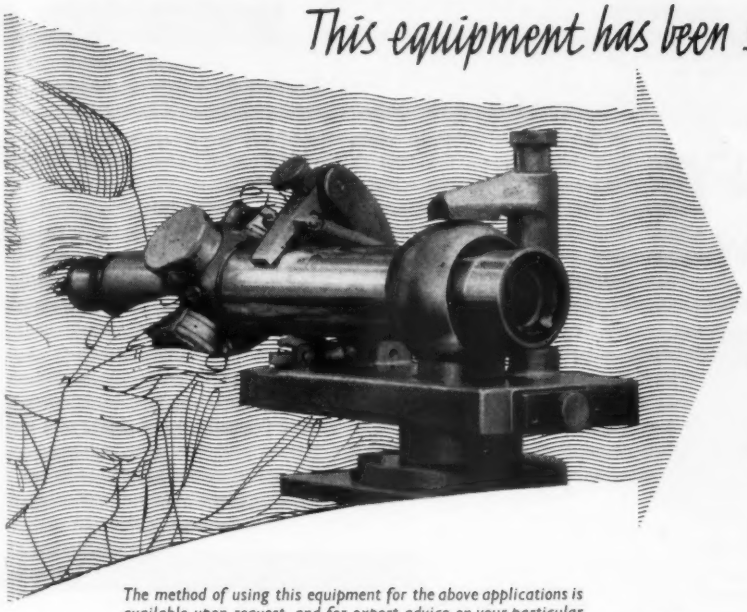
Supplied Only Through Your Wholesaler

Electrolube and Snorkel are Registered Trade Marks of ELECTROLUBE LTD., 16 Berkeley Street, London, W.1. 24-hour ANSAFONE service Tel. HYDe Park 0501 (5 lines).

Circle **No 122** on reply card for further details

'MICRO' ALIGNMENT TELESCOPE

This equipment has been successfully used by . . .



. . . the United Kingdom Atomic Engineering Research Establishment in the construction of Experimental Nuclear Reactors and the associated Projects ZETA, BEPO, ZEUS, ZEPHYR, DIDO and PLUTO. Also used by the leading manufacturing groups in the construction of Nuclear Power Stations, of the Power Supply Plan in Great Britain.

Sets and checks **ALIGNMENT PARALLELISM · SQUARENESS PLANE SURFACES**

The method of using this equipment for the above applications is available upon request, and for expert advice on your particular problem, please apply to Optical Tooling Engineers' Dept.

TAYLOR-HOBSON

A Division of RANK PRECISION INDUSTRIES LTD.

TAYLOR, TAYLOR & HOBSON, LEICESTER, England.

AT 29

Circle **No 123** on reply card for further details

D. A. E. P.

DOUBLE ACTING ENCLOSED WORM DRIVE PUMP

Suitable for:—Boiler Feed, Seawater, Fuel oil and viscous fluids up to 3,500 sec. Redwood I.

EFFICIENCY *High Duty/Power Ratio*

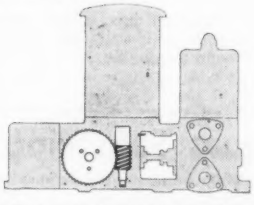
1700 G.P.H./200 P.S.I. — 7½ H.P.

to

57 G.P.H./150 P.S.I. — ¼ H.P.

ECONOMY Low current — requiring simple, inexpensive switchgear.

TROUBLE-FREE LONG LIFE WORM DRIVE



SEPARATE UNITS Individual gear box and pumping unit are bolted together. IRON, GUNMETAL or STAINLESS STEEL Pumps do not need the gear box in these expensive metals.

Suitable for all climatic conditions

Write for details to the manufacturers:

RICHARD GROSVENOR & CO. LTD.

53-54 VICTORIA ROAD, SURBITON, SURREY

Telephone : Elmbridge 7700-1

Circle **No 124** on reply card for further details

TO INDICATE CONTROL OR RECORD TEMPERATURE

For accuracy, ease of reading, robustness, economy and long, trouble free life install Rototherm Thermometers, Controllers and Recorders. Specialists in bi-metallic applications.

Write for details

Rototherm

BI-METAL · MERCURY-IN-STEEL · VAPOUR PRESSURE

THE BRITISH ROTOTHERM CO. LTD.

Merton Abbey, London, S.W.19 LIBerty 7661

Midland Factory: Hollis St., New Basford Nottingham 77847

Circle **No 125** on reply card for further details

ENDECOTTS
TEST SIEVES
For Accuracy!

POCKET INTERCHANGER SIEVES

'ENDROCK' TEST SIEVE SHAKER

TEST SIEVES
B.S. 410: 43 U.S. Standards and Tyler Equivalents

We operate a Recovering Service

Consistent mechanical action—
saves valuable time of skilled personnel

ENDECOTTS (FILTERS) LTD.
Dept. A. Lombard Road, London, S.W.19.
Phone: LIBerty 8121/2/3
Grams: Endfilt, London

Circle **No 126** on reply card for further details

for protection against radiation

look ahead with LEAD

not forgetting, LEAD GLASS

The technical officers of the Association are always glad to give individual assistance.
LEAD DEVELOPMENT ASSOCIATION, 18 Adam Street, London, W.C.2.
Telephone: WHitehall 4175 Telegrams: Leadevep, Rand, London

LDA1/60

industries atomiques

The international review for the peaceful uses of nuclear energy
A RENE KISTER PUBLICATION

Annual Subscription

12 numbers per year

French new francs	41,50
Belgian francs	510
Swiss francs	40
German marks	40
U.S. dollars	10
Pounds sterling	3/15/0

INDUSTRIES ATOMIQUES
is the only international technical and industrial review printed in French, which specialises entirely in nuclear and related subjects.

INDUSTRIES ATOMIQUES is read by industrialists, engineers, technicians and chemists, heads of technical firms and by all those engaged in the world of science. In short, it is intended expressly for all specialists interested in research and in its practical realisation.

In view of its international character, **INDUSTRIES ATOMIQUES** is read and appreciated in countries all over the world.

Up to date, more than 250 authors, all specialists, have honoured this review with their collaboration, and have contributed **previously unpublished** articles of high scientific value, abundantly illustrated.

INDUSTRIES ATOMIQUES is a source of precise documentation, constantly being brought up to date. The international information and the list of suppliers to the atomic industries printed in its pages will be found invaluable.

Industries Atomiques Subscription form

Subscriptions can be paid in the currency of the country at any European post office.

We desire _____ annual subscriptions, starting from _____, to be sent to (surname, Christian names, or firm's name, and address) _____

Method of payment _____ Date and signature:

(This form should be returned in a stamped and addressed envelope to NUCLEAR POWER, 77-79 Charlotte Street, London, W1.)

CLASSIFIED ADVERTISEMENTS

DISPLAY ANNOUNCEMENT RATES:— 1 insertion 50/- per single col. inch
6 insertions 47/6 per single col. inch
12 insertions 45/- per single col. inch

LINEAGE ANNOUNCEMENT RATES:— 5/- per line. 5% discount for 6 insertions, 10% discount 12 insertions

BOX Nos.:— 1/- extra will be charged

COPY DATE:— Advertisements for November issue to be received not later than October 10th

SITUATIONS VACANT

THE NUCLEAR POWER GROUP
requires
DESIGN
ENGINEERS

With the contract for Dungeness Nuclear Power Station, The Nuclear Power Group is now actively engaged upon the construction of four major Nuclear Power Stations as well as designs for new plants in the United Kingdom and Overseas.

Applications are invited from suitably qualified men for the following appointments:

1. SENIOR ENGINEER—To be responsible for the design and development of burst fuel element detection systems. Experience in this field is desirable, but not essential.
2. SENIOR ENGINEER—For the design of special reactor components, remote handling equipment and special mechanisms.

Applicants should be between 28 and 35 years of age and should hold a degree and be corporate members of the Institution of Electrical or Mechanical Engineers.

The positions will be tenable at the Group's offices situated in their own grounds at Knutsford, Cheshire.

Housing assistance will be offered to married men.

Applications, giving details of age, qualifications, and experience, should be addressed to:—

The Personnel Manager,
The Nuclear Power Group,
Radbroke Hall,
Knutsford,
Cheshire.
Quoting reference NP/ELEC/6.

SCIENTIST

required by the United Kingdom Atomic Energy Authority at Dounreay Experimental Reactor Establishment, Thurso, Caithness, Scotland, to assist in determining the performance of the fast reactor coolant circuits by carrying out practical investigations and theoretical analysis of results. The duties in the first instance will involve working on sodium circuits of the reactor and later on steam raising circuits. The successful candidate will be expected to participate in and contribute to the general development of the reactor.

Applicants should have at least a second class honours degree in mechanical engineering and preferably have some electrical knowledge. They should be prepared to specialise in heat transfer problems associated with liquid sodium heat exchangers and instrumentation and control of such circuits.

Starting salary will be assessed according to age, qualifications and experience on the scale £1365 to £1675 or £755 to £1250. For appointment on the former scale applicants must have at least three years' post-graduate experience and be at least 26 years of age.

Contributory Superannuation. Staff housing scheme.

Hostel accommodation available.

Send postcard for application form, quoting reference 367/J28, to Personnel Manager at above address.

COURSES

U.K.A.E.A.
HARWELL REACTOR SCHOOL
Standard Course No. 22

The next course will be held from 2nd January to 28th April, 1961, inclusive. The fee for the course is £250 exclusive of accommodation.

It is intended primarily for engineers and physicists whose main interest is in reactor design.

Control and Instrumentation of Reactors Course No. 6

This course will be held at Durley Hall, Bournemouth, from the 30th January to 10th February, 1961, inclusive. The fee for the course will be £52 10s. exclusive of accommodation.

It is intended for those who have a direct interest in the control and instrumentation of nuclear reactors, and it is assumed that participants have some knowledge of the basic principles of these subjects.

Senior Technical Executives' Course No. 12

The course will be held from 8th to 19th May, 1961, inclusive, of which the first week will be at The Reactor School, Harwell, and the second at Durley Hall, Bournemouth. The fee for the course is £52 10s. exclusive of accommodation.

This is an appreciation course for senior executives and gives the background to nuclear engineering.

Application forms and further details for these courses can be obtained from:—

The Manager,
Reactor School,
A.E.R.E.,
Harwell,
Berks.

LANCHESTER COLLEGE OF TECHNOLOGY, COVENTRY
DEPARTMENT OF APPLIED PHYSICS

Evening Course on
NUCLEAR ENGINEERING

A series of 14 weekly Wednesday evening lectures for Physicists and Engineers on Nuclear Engineering will begin on November 2nd, 1960, at 6.30 p.m.

Fee: £1 12s. 0d.

Full particulars and forms of application from the Head of the Department of Applied Physics.

ATOMIC ENERGY OF CANADA LIMITED

requires

PHYSICAL METALLURGISTS, METAL PHYSICISTS

and

CHEMICAL ENGINEERS

As engineers and scientists in the chemical and metallurgical fields for research and development in an expanding power reactor programme. Two heavy water moderated and cooled power reactors are being designed and built in Canada, and an organic liquid cooled heavy water moderated reactor is in an advanced development and design phase.

SPECIFIC REQUIREMENTS ARE—

Physical Metallurgists—

To take part in programmes on the development of new materials — zirconium alloys, sintered aluminium products, beryllium, etc. Irradiation effects and corrosion are studied.

Metal Physicists—

To initiate and carry out new research programs on the fundamental behaviour of materials under irradiation.

Fuel Development Engineers—

To participate in expanding programmes on the development and evaluation of fuels for the above power reactors. Experience in ceramics and metal forming would be useful.

Chemical Engineers—

To assist in projects on heat transfer and purification of organic liquid coolants and in other projects dealing with heavy water cooling.

In all these fields there are openings for junior men and for several senior men who are capable of directing the work of a group.

Salaries from $5,000 for new graduates to over $10,000 per year depending on experience.

Location will be at Chalk River initially but later may be at the Whiteshell Nuclear Establishment, Canada's new atomic research centre near Winnipeg.

Three weeks annual paid vacation. Accumulative sick leave. Good pension plan. Group hospital—medical scheme. Low cost health insurance. Assistance given in obtaining housing—Staff Hotel for single people. Opportunities for promotion.

Please give full details of education and experience in first letter. Reply to Atomic Energy of Canada Limited, Africa House, London, England. Interviews will be arranged.

AT YOUR SERVICE when you need an expert

C. W. GARRETT & SON LTD.,
for
ALL DRAWING OFFICE SERVICES, PROCESSES, MATERIALS AND EQUIPMENT
●
WINDMILL ROAD, BRENTFORD MIDDLESEX
Telephone : ISLeworth 4433 (4 lines)

ALUMINIUM DESIGN
and fabrication service available for all types welded and other light alloy structures and components
ALPHAMIN LTD.
4 Dunston Street, Kingsland Road, London, E.8. Tel.: CLissold 4161

PERSPECTIVE AND SECTION DRAWING
In colour, line and monochrome
Complete technical booklets undertaken
HILTON AND KAY LIMITED
4 Water Street, Manchester 3
'phone Blackfriars 0402. Est. 30 years
High quality Low costs

X-RADIOGRAPHY
of welds and castings offered up to 1¼" thickness, also high vacuum test facilities.
IMMEDIATE SERVICE
THOS. RYDER & CO. MANCHESTER LTD.,
COMMERCIAL STREET WORKS, KNOTT MILL, MANCHESTER 15
Central 6753

TECHNICAL TRANSLATIONS by a team of graduate experts, covering many technical fields and languages. P. Suchodolski, F.I.L.(Eng.), 70 Greenfield Gardens, London, N.W.2. Telephone: MEAdway 2239.

Higher Tensile Steel Chain Slings and special Lifting Appliances of every description D.G.I. approved
T. SMITH & CLARKE LTD.,
Chain Manufacturers,
Port Tennant, Swansea
Telephone No. 53106 (4 lines)

R. & J. PARK LTD
Dominion Works, Chiswick England
●
Export packers, shippers and forwarding agents. Specialists in packing heavy machinery

ELECTRICAL CONNECTORS

PLUGS AND SOCKETS
More than 1,000,000 in stock, covering over 50 different ranges, British and American
●
Stock list on application to:
SASCO
Nutfield, Redhill, Surrey
Telephone: Redhill 5050

Specialists in the analytical and mechanical testing of all metallic materials. Approved by D.G.I., Air Registration Board, Ministry of Transport, and Lloyds.
ACLOQUE (Metallurgists) Ltd.,
ABBey 1481
Test House, Garth Road, Lower Morden, Surrey. DERwent 6252

PRACTITIONERS IN THE ART OF SCALE MODELS AND PATTERNS
All types of scale models.
Quality — Delivery — Service
Contractors to the U.K.A.E.A.
●
MASTERMODELS LTD.
Greenhill Crescent, Harrow, Middx.
Telephone: HARrow 2428

SITUATIONS VACANT

CENTRAL ELECTRICITY GENERATING BOARD

ASSISTANT ENGINEERS

Applications are invited for two appointments as ASSISTANT ENGINEERS in the Planning Department at Headquarters. Both will be in the Development Section (Policy) as members of a group which advises on certain technical and economic problems arising from the continuous growth of the electricity supply industry and the increasing capacity of generating stations. The group also contributes to long term studies. An essential in each case is a capacity for forward thinking.

SECOND ASSISTANT ENGINEER

This appointment will be essentially technical administration work and will be mainly, though not exclusively, concerned with the economic data required for forward studies on all types of generating stations, whether coal, oil or nuclear fuelled. The applicant should hold a University degree or similar qualification and should have had experience in the electricity supply or the nuclear industries.

Salary on a scale within the range £1,385–£2,010 p.a. according to duties and responsibilities.

FOURTH ASSISTANT ENGINEER

This appointment will assist in dealing with problems relating to one or more of the following: Clean Air, Water Resources, Effluent Disposal, Economic Appraisals, Ash Disposal. Experience in one or more of these fields or in the Electricity Supply Industry would be an advantage.

Salary on a scale within the range £930–£1,375 p.a., according to duties and responsibilities.

Applications stating age, qualifications, experience, present position and salary, to the Personnel Officer, 24/30 Holborn, London, E.C.1, by 3rd October. Envelopes should be marked "Confidential Ref. NP/327."

Circle **No 128** on reply card for further details

Gears and Gear units

HIGEARS

After sales SERVICE

THE ESSENTIAL LINK FOR EFFICIENCY

We have a technical representative or an agent in your area backed up by a competent technical staff to give you expert advice. Call us in early in the design stage. We may be able to reduce the cost by advising one of our standard gear units.

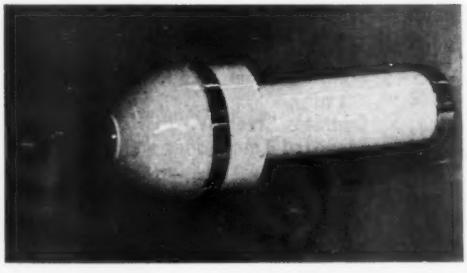
Further detailed literature from:

HIGHFIELD GEAR & ENGINEERING CO. LTD.

NILE STREET · HUDDERSFIELD · YORKS.

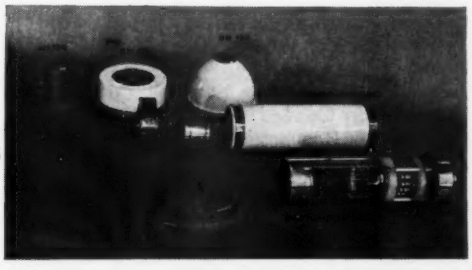
Phone: 4490/1/2 **Grams: "HIGEARS"**

UNIVERSAL SCINTILLATION COUNTER



BURNDEPT BN 120

A variety of: COLLIMATORS CRYSTALS USES.



A truly adaptable instrument which allows for several types of Collimators, different grades and types of Crystals thus making it a multi-purpose Scintillation Counter.

A Cathode Follower and Head Amplifier are available, designed to be truly compatible, comprising :

Brief Specification:

BN.120—Housing, Basic Unit
BN.121—Adjustable Clamp for basic unit
BN.122—Wide Angle Collimator
BN.123—Adjustable Clamp for use with BN.122
BN.124—Narrow Angle Collimator
BN.125—Lead Skirt
BN.126—Slotted Collimator
BN.127—Cathode Follower Unit
BN.129—Connector Signal, for use with BN.120 basic unit

Photomultiplier Tube: 20th Century VMP/11/44 or E.M.I. Type 6097B.
Scintillation Crystal: Hilger & Watts P.1031 1½" x 1" (other types of crystal can be obtained to order).
Power Supply Required: D.C. stabilised voltage variable up to 2 Kv. capable of supplying 50 microamps.
The BURNDEPT HEAD AMPLIFIER BN.106 and the BURNDEPT RATEMETER BN.110 are also ideal for use with the BN.120 and are available ex stock or at short delivery.

Items BN.120, BN.121, BN.122, BN.123, BN.124, BN.125, BN.126, BN.127, BN.129 can be supplied individually if required.

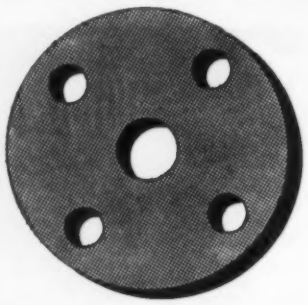
BURNDEPT

Enquiries to:

BURNDEPT LIMITED · ERITH · KENT

TELEPHONE ERITH 33080

Circle No 130 on reply card for further details



STAINLESS TUBES & FLANGES

We offer in approved grades of Stainless Steel

★ FLANGES MACHINED TO B.S. TABLES OR TO SPECIAL SIZES
★ SOLID DRAWN TUBES—FABRICATED PIPES
★ ROUND and HEXAGON BAR
★ PROFILES CUT TO ANY THICKNESS OR SIZE
★ CASTINGS TO CUSTOMERS SPECIFICATION

Keen Prices — Prompt Delivery

Send enquiries to Dept. N.P.

STAINLESS STEEL PROFILE CUTTERS LTD.

Farfac Works, Kings Grove, MAIDENHEAD. *'phone* 1522/23.

ADVERTISERS IN THIS ISSUE

Accles & Pollock Ltd 133
Acheson Colloids Ltd 19
Airmec Ltd 30
Albright & Wilson (Mfg) Ltd 5
American Machine and Foundry Co. 16
Armstrong Whitworth Aircraft Ltd, Sir W. G. 59
Associated Lead Manufacturers Ltd 20
Avo Ltd 33

Baker & Bessemer Ltd, John 134
Barlow-Whitney Ltd 149
Berry & Co. Ltd, Henry 122
Bettles & Sons Ltd 150
Bitulac Ltd 142
Bolton Gate Co. Ltd 144
Booth Aluminium Ltd, James 27
British LaBour Pump Co. Ltd 62
British Rototherm Co. Ltd, The 153
Burndept Ltd 157

Carlisle & Co. Ltd, C. G. 149
Central Electricity Generating Board, The 151
Colvilles Ltd 6
Consett Iron Co. Ltd 35
Consolidated Pneumatic Tool Co. Ltd 115
Crosby Valve & Engineering Co. Ltd 123

Datum Metal Products Ltd 144
De Havilland Propellers Ltd 7
Detel Products Ltd 126
Dewrance & Co. Ltd 8
Donkin Co. Ltd, The Bryan 146
D.P. Battery Co. Ltd, The 40

Edwards High Vacuum Ltd 17
Electrolube Ltd 152
Elliott Nucleonics Ltd 26
E.M.B. Co. Ltd 135
E.M.I. Electronics Ltd 121
Endecotts (Filters) Ltd 154
Evans & Son (Portsmouth) Ltd, J. 48
Evers, D. H. 125

Fairey Engineering Ltd 31
Fielden Electronics Ltd 55
Flight Refuelling Ltd 66
Frazar & Hansen Ltd 132

General Electric Co. Ltd, The 15, 128
General Radiological Ltd 11
Graviner 58
Grosvenor & Co. Ltd, Richard 153

Harlow Printing Works (Northern) Ltd 150
Harvey & Co. (London) Ltd, G. A. 141
Hawker Siddeley Nuclear Power Co. Ltd 127
Head Wrightson Processes Ltd 21
Heather Filters Ltd 126
Henderson & Keay Ltd 60
High Voltage Engineering Corporation 113
Highfield Gear & Engineering Co. Ltd 157
Hilger & Watts Ltd 122
Hoffmann Manufacturing Co. Ltd, The 142
Howden & Co. Ltd, James 159
Honeywell Controls Ltd 24

Imhof Ltd, Alfred 25
Imperial Chemical Industries Ltd 68
Industries Atomiques 154
Isopad Ltd 132

Th. Jansen S.A. 148

Keith Blackman Ltd, 23
K.D.G. Instruments Ltd 124
Kirk & Co. (Tubes) Ltd 146
Kodak Ltd 39

Labgear Ltd 147
Lang Pneumatic Ltd 137
Lead Development Association 154
Lincoln Electric Co. Ltd 4
Lyons Ltd, Claude 148

Magnesium Elektron Ltd 129
Mallinckrodt Nuclear Corp. 10
Mallinson & Sons Ltd, William 38
Marston Excelsior Ltd 44
Metal & Pipeline Endurance Ltd 124
Murex Ltd 130

Nuclear Power Group, The 2
Nuclear Measurements Corp. 152
Nuclear Equipment Ltd 64
Nuclear Enterprises (G.B.) Ltd 145
N.G.N. Electrical Ltd 145
Newton Chambers & Co. Ltd 54
Newalls Insulation Co. Ltd 34

Oxley & Co. Ltd, William 131

Pascall Engineering Co. Ltd, The 152
Payter & Co. Ltd, E. C. 138
Plessey Nucleonics Ltd 56
Powell Duffryn Carbon Products Ltd 51
Precision Rubbers Ltd 138
Pye Ltd 32
Pyrene Co Ltd, The 139

Q.V.F. Ltd 36

Radiospares Ltd 130
Rawlplug Co. Ltd, The 37
Research & Control Instruments Ltd 128
Rio Tinto Management Services (U.K.) Ltd 63
Robertson & Ferguson Ltd 50
Rotameter Manufacturing Co. Ltd 150

Sangamo Weston Ltd 136
Serck Radiators Ltd 57
Shell Mex & B.P. Ltd 42, 43
Simmonds Ltd, L. E. 140
Solartron Electronic Group Ltd, The 52, 53
Stainless Steel Profile Cutters Ltd 158
Stainless Steel Wire Co. Ltd 136
Standard Telephones and Cables Ltd 22
Stillite Products Ltd 45

Taylor, Taylor & Hobson 153
Texas Instruments Inc., Metals & Controls Div. 18
Thermal Syndicate Ltd, The 134
Thompson (Wolverhampton) Ltd, John 160

Unistrut Division of Sankey-Sheldon Ltd 117

Vacu-Blast Ltd 140
Vandyke Engineering Ltd 61
Vokes Ltd 14
Vokes Genspring Ltd 142

Wakefield-Dick Industrial Oils Ltd 12, 13
Wandleside Cable Works Ltd 49
Weston & Co. Ltd, Charles 41
Widnes Foundry & Engineering Co. Ltd 9
Wiggin & Co. Ltd, Henry 119
Williams and James (Engineers) Ltd 143

HOWDEN

Specialists in the design and manufacture of equipment for

MOVING OR COMPRESSING AIR AND GASES

TRANSFERRING HEAT FROM ONE FLUID TO ANOTHER

CLEANING AIR AND GASES

JAMES HOWDEN AND COMPANY LTD

195 SCOTLAND STREET, GLASGOW, C.5, and
15 GROSVENOR PLACE, LONDON, S.W.1

Circle **No 207** on reply card for further details

Nuclear Power
REACTORS · MATERIALS · INSTRUMENTATION · PROCESSES · IRRADIATION

Circle **No 208** on reply card for further details

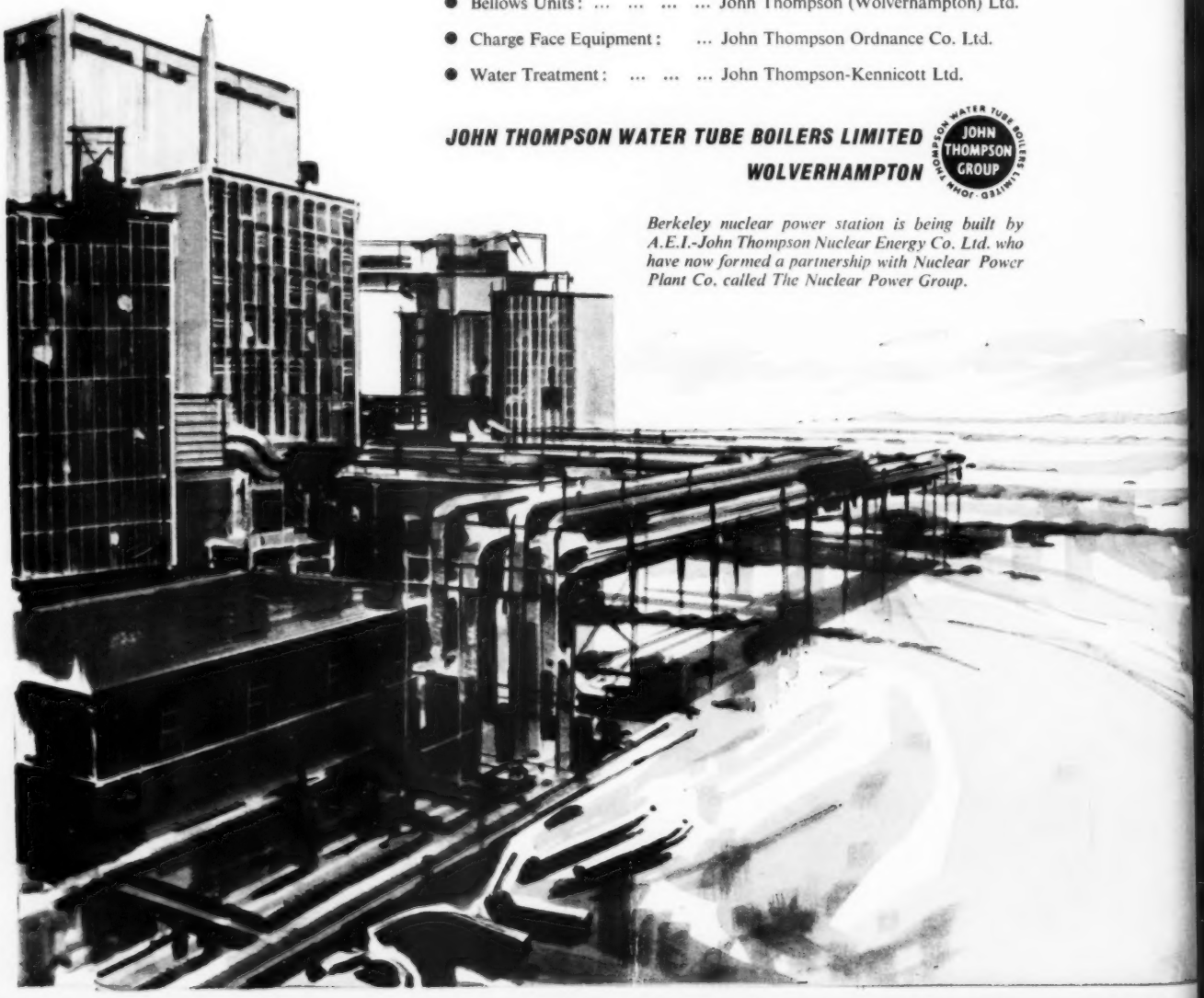
JOHN THOMPSON AT BERKELEY

"first in the world"

Commercial Nuclear Power Station

- Reactor Pressure Vessels: ... John Thompson (Wolverhampton) Ltd.
- Heat Exchange Shells: ... ... John Thompson (Wolverhampton) Ltd.
- Heat Exchange Internals: ... John Thompson (Pipework) Ltd.
- Steam, Feed & CO_2 Pipework: John Thompson (Pipework) Ltd.
- Windows, Galleries & Ladders: John Thompson Beacon Windows Ltd.
- Gas Ducting: ... ... John Thompson (Dudley) Ltd. and John Thompson (Wolverhampton) Ltd
- Diagrid: ... ... John Thompson (Dudley) Ltd.
- Bellows Units: ... ... John Thompson (Wolverhampton) Ltd.
- Charge Face Equipment: ... John Thompson Ordnance Co. Ltd.
- Water Treatment: ... ... John Thompson-Kennicott Ltd.

JOHN THOMPSON WATER TUBE BOILERS LIMITED
WOLVERHAMPTON

JOHN THOMPSON GROUP

Berkeley nuclear power station is being built by A.E.I.-John Thompson Nuclear Energy Co. Ltd. who have now formed a partnership with Nuclear Power Plant Co. called The Nuclear Power Group.